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# Plastics

*Dealing with the Manufacture, Uses and Potentialities of Plastic Materials*

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## Revenge

IT must be admitted that one of the chief aims of the plastics industry which deals solely with organic, that is carbonaceous, materials, is to replace many inorganic substances, metals and metallic compounds. Chemists have put many remarkable synthetic materials in our hands.

At the same time workers have been experimenting in the inorganic field and seem likely to provide one of the most amazing of discoveries in the realm of film formation. Hitherto the most widely employed films (other than thin metallic films) are invariably organic in nature, paper and other cellulose films, paints and varnishes, etc. And it is one of the disadvantages of most organic materials that they are inflammable and to a greater or less extent are attacked by moisture, chemicals, etc. In other words, a non-inflammable and virtually indestructible paper would be of great service to mankind.

It would seem that theoretically, at any rate, that point has now been reached. Doctors Hauser and Le Beau of the Massachusetts Institute of Technology have carried out some extended research on the film formation of bentonite, a clay with strange properties. This is a colloidal material which can be made into a coherent white sheet of considerable strength, replacing certain plastic films.

We do not know in which direction, or directions, commercial applications will proceed and have no right to particularize. But it is, nevertheless, intriguing to imagine a book made of the new material, a paint with no organic binder, so that it might withstand water, acid, alkalis and organic solvents equally well, a paint that really resists heat and not one made up of an organic film heavily loaded with aluminium powder as they usually are. Apart from the disadvantage that the hero in the drama could not burn the secret code before being caught, the balance would be to the benefit of the world. It has also been suggested that such a film would produce the ideal binder for mica for electrical purposes, since an organic binder has the dielectric strength of mica.

How serious an attack on, say, the paper industry this will one day be we cannot, of course, say. We believe the bentonite deposits are not tremendously large, but it is not beyond the bounds of possibility that physicists might be able to lead ordinary china clay into the same paths. But even so we must welcome such research. If Dr. Hauser is the famous physicist we met in Cologne some 10 years ago on the occasion of the visit of British rubber chemists, he has probably made use of his great knowledge of rubber physics and will, no doubt, by this very work help to solve some of the problems of the chemistry and physics of plastics.

## Motorcar Bodies

ELSEWHERE in this issue we publish some notes on the above subject by an American engineer in which he gives us the general attitude of motorcar manufacturers in his country to plastics as materials of construction. Also a subsequent article on another page divulges the attitude taken by a famous American motorcar manufacturing concern towards decorative plastics and some of the tests that are carried out on them to evaluate their suitability for the jobs. Both articles are extremely valuable to us, since the information therein deals with an industry which tests plastics very thoroughly both from engineering and economic viewpoints.

At first reading both articles would probably damp the ardour of many a plastics enthusiast, especially those who are not engineers, but closer examination discloses the desire of both writers to give helpful criticism to the plastics industry and to point the way for future efforts. Clarification does not necessarily imply disillusionment. Indeed, scientifically the world is progressing steadily towards stronger and lower cost plastics and simplified methods of using them, each and all of which would solve many problems in motorcar production.

The news that the Ford Company is experimenting on a type of plastics made by a process akin to paper manufacture, that is by impregnating floating and orientated fibres with, presumably, an emulsion of resin, is extremely interesting. But the

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method is by no means new to readers of this journal since the plastic so made bears a striking resemblance to the German Peton and to the British material Hyten. The latter is now apparently unobtainable—a most unfortunate condition. We described both in our issues of 1937, and indeed suggested that the plastics in sheet form would serve as moulding materials for motorcar panels. The strength of such finished goods is surprisingly high.

Apparently no work analogous to the researches by the Auto-Union on impregnated plywood structures is being carried out in the U.S.A. Doubtless we shall learn a great deal from the methods employed in plastic aircraft manufacture, for this avoids the use of expensive moulding tools. Greater progress would also be brought about if plywood were amenable to double curvature—a situation that is far from being attained. It has been suggested that the motorcar industry is somewhat too "thermo-setting minded" and should turn its attention to certain thermo-plastics which would prove much more amenable to simple moulding or shaping. Indeed, there is little doubt that were it possible to make large and fairly smooth sheets of pure polyvinyl chloride or acetate (that is without plasticizing or softening agents) the motorcar industry would have a material as strong and as tough as could be desired. From the initial cost point of view these valuable plastics become merely of academic interest.

Parallel work on motorcar production in this country is non-existent and we must regret the years the locusts —or rather Hitler—have eaten. On the other hand, we may catch up after the war and utilize some of the specialized knowledge on construction many have gathered in similar but more warlike spheres of activity.

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**NON-ICING SAFETY GLASS.**—A new method of producing an organic glass which prevents the adhesion of snow and ice has been described by Rideau and Ducret in a recent number of *Les Ailes*. The authors point out that the use of brush-on de-icing compounds, and of special double-walled observation windows, is fraught with some difficulty. In the new system, the usual safety-glass construction is adhered to, but, in addition, on the inner side of one of the glass sheets are laid a number of fine wires, 0.05-0.1 mm. diameter, 2-5 mm. apart. The ends of these are brought to the outside of the pack, reinforced by sprayed-on metal contacts through which an electrical current may be established. Units are made up for 12, 24 or 110-volt supply, the consumption being about 10 $W/dm_2$ for an air speed of 300 km/h. About 4 mins. is required for the pack to attain its working temperature. Visibility is not impaired, it is stated, as the heating wires are so extremely fine.

**THE HARDWARE TRADE.**—In the "Inquiries and Answers" section on page 82 of this issue we give yet another photograph of two plastic ball-floats for water cisterns made by two different concerns who supply some of the biggest factors in the hardware trade. The importance of such manufacture is, of course, especially great in war-time, for they replace metal floats which are almost invariably made of copper, a metal that becomes a rarity for general consumption. To engineers, the problem is of still greater interest, since it has been proved that the new type of float is adequate for the purpose and is not likely to lose its popularity in time of peace. While they are light in weight, lightness is not the main criterion of value. Of outstanding importance are the resistance of the material to continual contact with moisture and strength to withstand adequately the forces created by ice-formation at low temperatures. It is by the construction of such eminently satisfactory jobs that the plastics industry will receive the commendation of that most-difficult-to-satisfy individual, the engineer.

**INSULATION MATERIALS.**—The chief physical properties of a wide range of materials suitable for electrical insulation were described in a recent paper by Mr. P. C. Walmsley, of Micanite and Insulators, Ltd., before the Association of Supervising Electrical Engineers. He opened his talk with a reference to the British Standards Institute method of classification of such material and then described the various methods of producing the insulators. The most important of recent developments is being observed in the production of insulating papers, the manufacturers concentrating on producing a high uniformity in structure and thickness. Cotton and sulphite-treated wood plup known as kraft are mostly employed for wrapping and as spacers, subsequently impregnated; manilla and jute are of limited application, principally as reinforcing agents. The utility of paper pressboards, presspahn and similar materials when correctly applied has proved itself according to the author of the paper, who also expresses the opinion that if the properties of these materials were better appreciated there would be an even greater number of users.

Among oils and resin impregnants, shellac formed by lac inserts on certain trees in India has given way to synthetic media, but still remains pre-eminent in certain high voltage applications when low working temperature enables its electrical properties to be utilized. From phenol and formaldehyde resins are formed which are soluble in alcohol and are used for coating and binding or for hot moulding. Recent practice leans towards the greater use of inorganic compounds in built-up forms with binders.

**DEVELOPMENT OF POLYVINYL RESINS.**—In a paper read before the Toronto section of the Society of Chemical Industry, Mr. G. O. Morrison, of Shawinigan Chemicals, Ltd., Quebec, described the origin of these remarkable plastics made from acetylene. Acetylene, he said, can be made to combine with acetic acid, in the presence of mercury, to form vinyl acetate which polymerizes easily to give products of varying viscosity and molecular weight. These polymers are called Gelvas, several of which are made giving molecular weights of 4,300 to 100,000. From these Gelvas can give rise to bodies, polyvinyl alcohol and products similar to it, known as Solvars. These can be made to combine with aldehydes to form other plastic compounds, e.g., Formvars and Butvars, all of which have found important industrial applications. Gelvas are used in lacquers and adhesives. Solvars find uses as adhesives, emulsifying agents, etc. Formvars make excellent mouldings, and interlayers for safety glass. Alvars are used for making phonograph records, mouldings, and Butvars in adhesives and safety glass.

**ARMSTRONG MEMORIAL FUND.**—Most living British chemists have been influenced in their scientific lives by the teachings and writings of the late Professor H. E. Armstrong, who probably had more influence on the chemical industry during the past 50 years than any other British chemist. A memorial fund has been inaugurated to commemorate his life and work, and it has been decided to present a bronze bust to the City and Guilds College, and also to establish a trust fund to be devoted to the publication of a work of major importance within the domain of Professor Armstrong's work. Over £1,000 has already been subscribed for the second part of the scheme by the Distillers Co., Ltd., Anglo-Iranian Oil Co., Imperial Chemical Industry, Ltd., Messrs. Albright and Wilson, The Fleischman Co. of U.S.A., and others.

# *The Open Sesame*

WHEN the piping times of peace are once more with us and moulders and fabricators can turn their thoughts to gentler things, we hope to see a wider use of the artistic talent that undoubtedly exists in this country. Mr. Landsberger, of Ambrican General Trust, Ltd., has shown us examples of door-handles which he introduced on the Continent a few years ago. For beauty and grace we have not yet seen their equal and we hope that the present conditions will enable him to manufacture their like here for our richer and appreciative friends on the other side of the Atlantic. As will be observed, Mr. Landsberger is not afraid of using plastic-metal casting combinations to the advantage of both.

*"The time and thought spent on the designing of plastics as such, bear a very close relation to the success of the finished goods"*

# Decorative Plastics for Automobiles

THE notes which follow are abstracted from a contribution by W. J. McCortney, of the Chrysler Corporation, Detroit, written for *Industrial and Engineering Chemistry*. They should be read in conjunction with the article on p. 70.

No single decorative plastic even approaches engineering standards for satisfactory use in the automobile. However, most of the characteristics desired can be found separately in the many classes of plastic now commercially available. Many of these plastics have a number of the desirable characteristics, but no single plastic has all. Until the universal plastic is developed, the engineer must be careful to select the one that has the particular qualities necessary for the application. To be of any value, this paper must name the materials now used in the automotive industry and discuss the good and bad characteristics of each.

To understand the conditions these plastics must withstand, it should be recalled that automobiles are used in ambient temperatures below −40 degrees F. Also, the instrument panels and plastic parts in the interior of the car heat up to approximately 60 degrees F. over out-of-door temperatures. This condition is most critical when a car is left standing in the sun with the windows closed. Exterior car temperatures on the flatter surfaces may be 70 degrees F. in excess of outdoor temperatures, but projecting parts not normal to the rays of the sun are considerably cooler.

Many of the plastics are moulded over metal inserts and fastened to the metal in such a way that shrinkage and distortion subject the piece to excessive strain. We have found that it is almost impossible to specify plastics by scientific means. Instead, we endeavour to specify the conditions that plastics must fulfil in our laboratories and in most of our testing on completed parts. In comparing new plastics it is customary to mould them into parts whose shrinkage and warping characteristics are already known.

### Decorative Plastics in Contact with Lacquer

The following is part of a typical example of a specification on plastics:—

1. This specification covers decorative plastics for interior use in locations where they will be in contact with, or less than ¼ in. from, lacquer-coated parts.

2. Plastic materials covered by this specification shall not soften, discolour, or otherwise damage the finish of nitrocellulose-lacquered parts with which they are in close contact. A quick test for this property may be made by placing a sample of the plastic material on a lacquered panel in an oven for 24 hours at 175 degrees F.

3. The colours of all plastics shall be referred to by Chrysler plastic colour numbers. Approved colour chips for these colours may be obtained from the Chrysler Plastics Laboratory. All samples of plastic materials submitted to match a particular Chrysler colour must be approved through the Plastics Laboratory. Such an approval must be secured by the moulder for each individual part before a production quantity is made.

4. All finished parts must withstand a hot and cold test, where they are subjected to a temperature of −40 degrees F. for 24 hours, 175 degrees dry heat for 24 hours, another 24 hours at 40 degrees, and, finally, 24 hours at 175 degrees with 65-70 per cent. relative humidity. During this cycle the piece must not shrink in excess of 2 per cent., warp, discolour, or crack under the load or stress required in production usage. The surface shall not craze, become wavy, tacky, or other wise unsightly.

5. The flow hardness of the material to be used on any particular part is not specified. Each moulder must, however, report to the Chrysler Engineering Laboratories the trade name, composition and flow hardness of the particular material finally approved for each part. Subsequent changes must also be reported.

We realize that this is only the beginning of plastics control and that greater improvements must be made.

### Plastics in Use

The decorative plastic now enjoying the greatest use is cellulose acetate. It has average resistance to heat, is obtainable in a good range of colours with the exception of water-white, and is usually handled by injection moulding. It will not withstand outdoor exposure, high humidity, or excessive heat and cold, especially when moulded over large metal inserts. The tensile strength of cellulose acetate is only moderate, but is extremely tough and non-brittle. It cannot be used in large sections without other support. Most acetates should not be used less than ¼ in. away from painted sheet metal. In such locations the various slightly volatile plasticizers condense on the painted metal, softening paints and lacquers with which they come in contact. For this reason we do not use cellulose acetate in such places, but confine its use more or less to handles, knobs, and hardware trim.

Cellulose acetobutyrate has largely replaced the acetates on such parts as are in close proximity to lacquered and painted surfaces. The different plasticizers used for acetobutyrate have no effect on paints and lacquers. Cellulose acetobutyrate is also more resistant to shrinkage in heat due to slight loss of plasticizer, and in the cold it is tough enough at the lower temperatures to resist cracking when applied over large inserts. Cellulose acetobutyrate is also a good weathering plastic and can readily be used on parts exposed to the weather.

Methyl methacrylate resins are used particularly where water-white plastic is desired for an edge-lighting effect. Cast methacrylate will withstand any temperatures encountered by the automobile body. Compression moulding compounds have been improved so that they will withstand most of the conditions. Injection-moulded methacrylates, however, are only fair for heat resistance and should be used only with the greatest of care. It can be said, however, that these two are improving rapidly and within a short time should be satisfactory for many more uses.

Styrene resins have many desirable characteristics in that they are stiff and of higher heat resistance than most of the thermo-plastic materials. Although somewhat more brittle than thermo-plastics in general, we can still find great use in the automotive industry for a strong, clear, transparent or light-coloured plastic. Styrene resins are used now only in places where high heat resistance is required and where the plastic is shielded from any possible contact with gasoline or cleaning fluids—for example, instrument pointers and dials. Hundreds of safety solvents are sold over the country, and all of them will change styrene polymers into a gummy mass on contact. Gasoline has less effect. We have been assured that there is a good chance that this weakness will be overcome.

Moulded phenolics are used in places where brittleness is not too great a factor and where darker colours or painted parts can be successfully used. Phenolics are also used as inserts for the brighter thermo-plastics.

Urea-formaldehyde plastics were probably the first light-coloured plastics to be employed in the automotive industry, but were originally discarded because they could not be injection-moulded and were not available in the depth of colour that we now desire. These resins are now available in a good range of colours and are only awaiting new methods for economically moulding thermo-setting plastics.

Cellulose nitrate, the old-timer of thermo-plastics, still finds important usage in the automotive industry.

# Ideas—

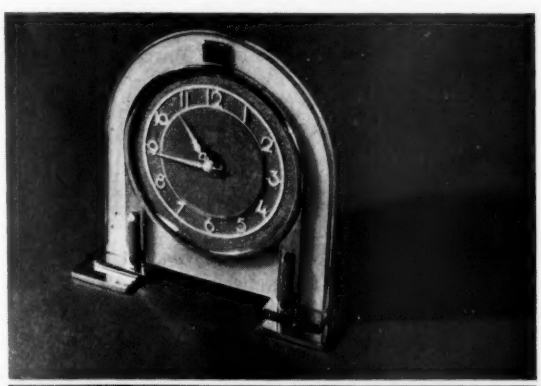
## By the EDITOR

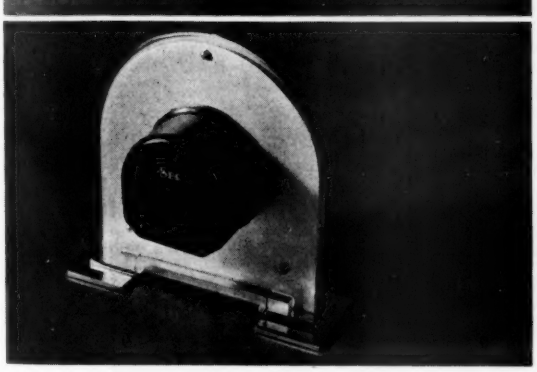
**Silk Parachutes**

A reader writes and asks whether parachutes for airmen have been made of viscose or cellulose acetate or other plastic fibre in view of the shortage of real silk. While I am rather timorous of giving secrets away to the enemy I think it is fairly well known that acetate silk has certainly been tried and is probably used for the purpose in some countries. Moreover, an American journal has published the fact that nylon is a most suitable material for the job and is, in fact, being so employed. We have heard rumours of it being used here too, to help out the silk shortage, but that is very hush-hush.

**Dust-proof Clocks**

One of the most interesting developments of moulded plastics is that adopted by the clock-making industry where totally enclosed housings for the works are such an attractive proposition. The metal stampings used normally are not very pretty things nor are they efficient, leaving loopholes for the entry of dust, which also means tarry and acidic accretions. The plastic moulded cover is especially applicable to the electric clock and as will be seen from the attached





photographs of a recent example made by S. Smith and Sons (M.A.), Ltd., utilizes a dustproof cover of clean design and is virtually incorrodible. No doubt the clock-making industry have realized the benefits of plastics from the electrical industry to whom our own industry will be ever grateful for the extension of the use of plastic moulded goods in ancillary industries.

**Polystyrene Lenses**

Strangely enough, polystyrene has not been looked upon as being one of the organic glasses, which have usually signified celluloid, cellulose acetate or the methyl methacrylate resins. This is, presumably, because polystyrene is not available in sheet form. However, it now jumps into the "glass" arena, with the manufacture in America of lenses for magni-

fying purposes, as the attached photograph shows. This plastic, the makers' pamphlet says, is "distinguished by flawless transparency, is tough and strong and much less fragile than glass." The moulding powder is made by the Monsanto Chemical Co. and the Waterbury Button Co. mould the lenses.

**Standard Prams**

Yet another blow has been dealt the metal industry through war conditions by the new restrictions placed on the manufacture of prams. I understand that the Board of Trade intend to reduce by half the amount of metal used by the manufacturers. No pram will be allowed to contain more than 12½ lb. of metal and since normally the quantity is about 30 lb. the pram manufacturers are extremely worried. This information was followed by a visit from an individual interested in the trade, with great hopes that plastics would solve the problem. He was greatly disappointed to find that because of the control of plastics the industry cannot hold out much hope. Were there sufficient material available how could it help? He pointed out that the main metal parts are wheels and axles, handles, springs, cross-strengthening pieces, hood-supports, etc. Axles and handles are probables, as are cross-strengthening pieces in general, and I suppose the extruded type of rod or tube would be suitable. But plastic springs are out of the question and hood-supports are highly improbable owing to the extraordinary wear put upon them. The wheels are possible, but would probably have to be specially designed. Cut from a laminated impregnated fabric block and fitted with a rubber tyre, such a wheel might prove efficient. Comparative costs might be frightening.

# Embellishing the Radio Cabinet

By a Special Correspondent

IT will be acknowledged that there has been little effort to alter radically the appearance of a plastic radio-cabinet other than by shape, and therein probably lies at least part of the reason why the plastic cabinet has moved forward but little, if at all, as an attractive commodity for public consideration. In fact, the 1941 moulded cabinet remains almost the same in surface appearance as the 1930 unit.

While there is not much object in apportioning the blame for this state of affairs, there is little doubt that in general the British radio industry regards the plastic object as a cheap substitute for expensive woods and, in consequence, turned to the moulding industry for cabinets destined for its special lower-priced market. It has rarely originated new designs. On the other hand, neither has the moulding industry, with one or two exceptions, initiated new designs for consideration by the radio-industry. There is, of course, a very good reason for this, since the public taste is a queer and fickle thing and it is not a happy situation to be left with a costly mould if the idea does not catch on. So much is obvious. Furthermore, and in many respects rightly, too, the moulder can rarely have a special sales organization to develop such sales. Close contact with a distinct sales organization or factor is generally just as useful and even more efficient.

It is quite clear, however, that a new consideration of plastic cabinets must be made on a wider basis, not merely covering structural design, but also surface decoration of all types, in order to lift this important section of the plastics industry out of the rut into which it has fallen.

It seems strange that the very advantage of plastics in being so readily mouldable is in one important sense a disadvantage. The very virtues of moulding an object often very complicated in one stroke are dimmed when colour relief is sought. We cannot, at any rate by simple means, put two differently coloured powders into a die and get a sharply defined line between them; the colours bleed one into the other obviously. Practically, it can only be done by joining separate mouldings together. Even this process has rarely been carried out, for again the price obsession seems to hang over the industry like a cloud of poison gas. It is just as harmful. This state of affairs is happily non-existent in the U.S.A. where bands or bars of beautifully contrasting resin are introduced into the motif. This is most apparent with the small cast resin cabinets.

Obviously, any method whatsoever entails additional processing or finishing, and is bound to send up the price, but it is certain that the public would be content to pay the additional cost if only the finished goods were made more eye-satisfying. The mournful blacks, ubiquitous mottles which pass, for some strange twist of certain minds, as beauty, and the marvellous walnut and mahogany imitations that make sundry engineer-designers burst with pride, must either be relegated to the place they deserve or relieved by some means or other. Moreover, the larger the cabinet the greater does this necessity become. That some relief is necessary is realized by most moulders and is shown by the concession of introducing coloured knobs and dials. On the other hand, the production of large cabinets in a single light colour does not avoid the need for further decoration.

*(Continued on page 75.)*

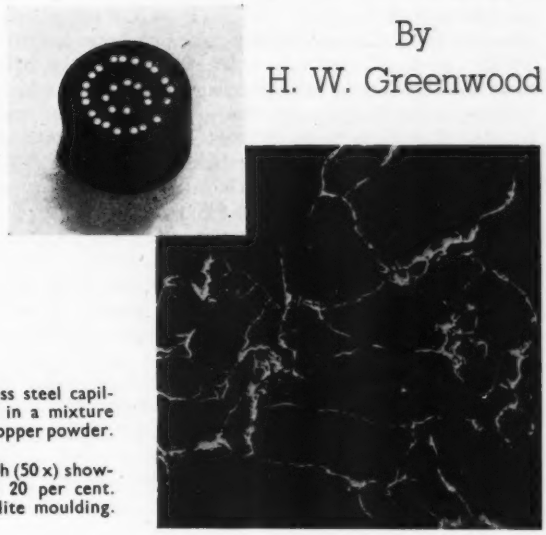
Right: The bars across the loud speaker of this cabinet are presumed to be covered with metallized lacquer.

Left: A suggested use of strip or sprayed metal in order to break up the surface of the moulded cabinet.

# Plastics *and* Powder Metallurgy

By
H. W. Greenwood

*In our March issue the author argued in general terms on the desirability of altering some of the properties of plastics by the addition of metal powders and the trend which such changes may take. In the following notes he deals with a specific change: that of hardness*



Above: Stainless steel capillaries mounted in a mixture of Bakelite and copper powder.

Photomicrograph (50 x) showing network of 20 per cent. copper in Bakelite moulding.

PLASTICS, compared with many other materials, are soft. That property carries with it advantages because its possession involves other physical properties of real value, such as resilience, absence of undue brittleness, resistance to shock, etc. If we desire to modify some property such as the softness of plastics we must do so without unduly affecting these valuable qualities, which depend upon or vary with the property we desire to modify.

It is very difficult to provide an example of any procedure which is universally applicable, so in describing how metals in powder form can be used to vary the hardness of plastics it will be convenient to take as simple a case as possible, to describe it so that anyone can understand why we wish to influence the hardness, how we can carry it out, the factors we must consider and the variations we can make.

This simple example can then act as a guide to those who desire to investigate similar possibilities in other directions. It will indicate a useful order of operations; first the problem to be tackled, wherein the difficulty lies which calls for modification, the general means to be employed, the materials to be used and their properties, the variations necessary and how the best conditions and quantities can be determined.

## Metallurgical Specimens

The example chosen comes from the metallurgical laboratory. Most people know that the metallurgist uses the microscope to a very large extent in his study of metals. He prepares specimens of metals and alloys for examination by grinding and polishing a surface until it is absolutely plain and free from scratches or markings, then he etches the surface with a suitable reagent and studies the structure of the metal which his procedure has revealed. The metallurgist has long realized what an excellent mounting material the plastics afford, and has used both opaque and translucent Bakelite and other plastics to mount his specimens, so that they could be conveniently handled during the processes of grinding, polishing, etching and examining under the microscope.

Unfortunately plastics have one serious drawback from the metallurgist's point of view. They are very soft compared to the majority of metals he is interested in. The result of this is that in the process of grinding and polishing the plastic mount tends to wear away much more rapidly than the specimen of metal, so that soon the latter stands up from the surrounding plastic matrix and its edges suffer.

They are ground away, and so instead of the finished metal surface being a true plane, it slopes away at the edges and so makes examination with high magnification very difficult, if not impossible. There is the metallurgist's problem. How can he modify the hardness of the plastic so that its rate of wear shall be approximately that of the metal specimen?

The answer is that because he can incorporate material in the plastic without seriously interfering with its moulding properties, and because metal powders are available covering the widest possible range of hardnesses, the solution of his problem is not difficult.

First comes the choice of metal powder; that will be determined by the nature of the specimen that is to be mounted. Metals vary in their hardness over a much wider range than many people realize. Obviously it would be very foolish to mount a soft lead alloy in a plastic reinforced by steel powder; such a procedure would be even worse than mounting a tool steel in a soft plastic. The metal powder should, therefore, bear a direct relationship to the specimen. If the latter is, for example, a cast iron, then the powder should preferably be a cast-iron powder of not too dissimilar a composition and hardness. The whole point of this is to ensure that both the specimen and the mount shall wear down at approximately the same rate, and therefore shall offer approximately the same resistance to the abrasive, and shall react similarly to etching.

## Importance of Particle Size

Having decided which metal or alloy to use, the next question is whether one particle size has advantages over another, and whether particle form plays an important role or not. Particle size is often a matter of the highest importance in powder metallurgy, and it is not without importance in a comparatively simple problem such as that we are considering. We are thinking of a certain area or space, not an empty space or one merely filled with air, but one filled with plastic, and we want to know what quantity of powder will most efficiently fill that space for our purpose and what size of particle will help most to attain the best result we can get.

We cannot use too large a particle, otherwise we shall have peaks and hollows formed during our grinding process; we may also have trouble through too large areas of soft plastic or hard metal existing side by side. Hence, so far as size of particle is concerned, we shall find that our particles should all be small enough to pass

a 150 mesh sieve—that is, a wire mesh sieve with 150 meshes to the linear inch. Also at least half the powder should pass a 200 mesh sieve. Such particle size will usually be found convenient for most purposes where metal powders are to be added to plastics for moulding.

Now comes the quantity. Here experiment alone can decide. It will be useful to start with 20 per cent. by weight; note particularly by weight, not by bulk. At this stage the fact that densities of metals range from below 1.0 to over 20 must be remembered, while the average specific gravity of plastics is about 1.3. Suppose that copper is the metal to be used as powder. It has a density of about 8.93, as against average plastic 1.3. If we take 20 per cent. by weight of copper powder it will not be one-fifth the bulk of the plastic, but only one-seventh of one-fifth.

In our particular example this is not, perhaps, of great significance, but if we were considering the addition of metal powder to a plastic for decorative purposes, or with a view to influencing some other property as well as hardness, such as heat or electrical conductivity, then this question of bulk in relation to effect would be very important from the costings point of view. We should remember that bulk will vary with density, that a metal like aluminium with a density of 2.7 will weigh just about double that of plastic for the same bulk, but that with the heavier metals the ratios will be very different.

In our particular example particle form will not play any important part; most of the powders available will serve our purpose without considering whether they are spherical, dendritic, lamellar or angular, and very generally this will also apply to the use of metal powders in plastics.

So we have traversed a very simple case of the use of metal powders in influencing hardness. The principles involved will apply to almost any other use of metal powders in the plastics industry to a similar end. The amount of experimental work involved in any particular case may well be quite large. If properly carried out it ensures smooth working and freedom from snags when the actual production stage is reached.

# PLASTICS *for motorcar bodies*

By An American Commentator

*An objective discussion of the application of plastics for the construction of motorcar bodies, with special reference to the work carried out by the Ford Co. in the United States*

IN looking through a file of *Plastics* recently, I found, in the May, 1940, issue, under the heading, "Design for the Moulded Car Body," a summary of the article by George W. Walker appearing originally in the March 4 issue of the American publication, *Automobile Topics*. With this is an illustration bearing the caption: "An artist's conception of the moulded plastic car of to-morrow—or may be the day after!" From these one gets the impression, although it may be a mistaken one, that Mr. Walker belongs to that school of artists endowed with the ability to make most attractive pictures of what "might" or some day "will" be done with plastics, but lacking the faintest conception of how such things can be brought about on any practical, quantity production basis.

Since there are recurrent at the present time in

America well-authenticated reports of plastic body developments on which the Ford Motor Company is working, it is instructive, first, to review the reasons why plastic motorcar bodies have appeared impractical, and still appear unlikely, in the present state of the art; second, to outline what Ford is doing toward overcoming the problems which stand in the way and why; and, finally, to point out how far from reality some of the visionaries are.

### Shortcomings of Plastics

One first should consider the attitude of the automobile engineer who knows the possibilities as well as the shortcomings of plastics and who also is well informed on the design and production of the highly successful and, on the whole, quite satisfactory all-steel body in common use on all American cars now produced on a large quantity basis. Such an engineer is likely to present his views, in substance, somewhat as follows:—

(a) Plastics as a class, and especially those at the low end of the cost scale, are deficient in strength. Evidence is lacking to show that they will withstand the shocks, weavings, stresses and vibration encountered, at least unless they are reinforced by fibrous content of some kind which is known to increase cost materially and to make moulding excessively difficult.

(b) Plastics promise to be much too costly in comparison with steel and to be lacking in several of the advantages which steel yields.

(c) Moulds are extremely costly and are operated on a cycle many times longer than that involved in using dies to form steel in equivalent shapes.

(d) Experience with really large mouldings is slight and the largest which have been produced, Ford's recent development excepted, have not established a record such as to beget confidence in respect to freedom from cracking, dimensional permanence and ability to withstand weathering.

(e) Press equipment needed promises to be of extreme size and too costly to warrant the investment presumably required.

(f) Repairs to bodies damaged in service involves unknown factors and promises to be costly.

(g) A steel frame is almost certainly essential and its cost must be added to that of the plastic shell, whereas the steel body, by simple flanging and related operations, is made to form its own frame of proved structural soundness.

(h) Present experience and facilities for steel body production are adequate and the bodies themselves are known to give satisfaction. Why change to a form involving many uncertainties, probably higher costs and certainly requiring a revolution in manufacturing methods, the scrapping of huge investments in equipment and the need for retraining skilled personnel to accomplish a result which, at best, may prove economically unsound?

Truly, this is good logic and so sound that it may be rather hard to understand how a practical and experienced manufacturer such as Henry Ford (who has the development under his personal supervision) is evidently trying to overcome the seemingly almost insuperable difficulties.

The answer lies, of course, in Mr. Ford's passionate devotion to the basically sound philosophy that, since the farmer needs manufactured goods, industry should make as much use as is feasible of farm products. This philosophy led to the Ford developments in soya bean products (in which soya plastics happen to be a minor consideration) and their demonstrated success seems to have increased Mr. Ford's desire to develop a body in which farm products will play an important part. Strangely, from one point of view, the present Ford plans do not call for using the soya plastic in the body except, perhaps, as it may enter into enamels applied in finishing. But Ford does plan to use some strong fibres, such as flax or ramie, in the plastic which is being developed for the purpose.

Ford logically started first (about two years ago) to develop a plastic believed to possess adequate strength. A phenolic binder is now being used and appears likely to be continued. It does not, of course, come from the farm. The filler and strengthening element of the plastic includes the agricultural fibres mentioned and sulphite wood pulp, such as is used in paper making. And the Ford plastic is made in a set-up resembling in some respects that in paper mills. The plastic binder is added while the fibres are separated and suspended in water in a " beater " or other agitator and, presumably, is absorbed to a greater or less extent by all the fibres. Then the fibres are coagulated and sucked off on to screens shaped (and this is important) like the panels to be moulded.

Water is then pressed from the preform (for that is what it is) and it is dried in an oven. It issues ready for moulding and in a shape which will fit the mould, thereby solving the problem of distributing the plastic as required in the mould, so that only very little flow occurs or is required. Ingenious!—but how expensive remains to be seen. It is noteworthy that the plastic thus formed has a composition closely resembling that of some laminated plastics, but it is not laminated. The fibres are disposed in random fashion and this is claimed to give uniform strength in all directions and to avoid warpage. No engineering data on strength have been given out, but some large panels have been moulded and are said to have shown ample strength and rather remarkable shock resistance.

### Size of Moulded Units

It should be said here that Ford has not indicated any intention to try to mould a whole body, or even any very large sections, as one-piece units. The body shell is to be constructed from relatively small panels, both to enable the use of moulds of moderate size (though very large as compared with plastic mouldings commonly called large) and to avoid deep draws. Panels are not to be flanged or to have surfaces approaching or lying at right angles to the direction of pressure applied in moulding, but they will be curved, it is assumed, enough to provide a well-rounded body.

Panels thus moulded are to be attached to a frame of steel tube, some major members of which are arched over the roof. The ends of these tubes (and joints with intervening tubes) are to be welded to longitudinals which take the place of a conventional chassis frame, making the body frame and the chassis one piece, in which roof tubes form a part of the girder-like assembly. This unit will carry normal chassis units (engine, etc.) and be supported by springs and running gear, a construction claimed to save some 200 lb. in total weight over current production cars, including the body shell in both cases. The plastic body shell is estimated to weigh 155 lb. and to constitute some two-fifths of the total weight of the unit, steel accounting for the remaining three-fifths. Significantly, the plastic panels are not to be rigidly mounted, but flexibly attached to the tubular frame by some method yet to be worked

out. This may involve inserted flat-head studs moulded in place in the plastic panels.

By this means the plastic is protected against twisting stresses and panels are made removable for ready replacement. How joints between panels are to be made is not yet disclosed. Doors are expected to have separate steel frames, but their lower panels at least will be plastic. By adopting these expedients, a variety of problems appear to be solved, although that of cost is yet to be determined and probably will not be until much more experience is gained. Moulds for a complete experimental body shell are said to have been ordered, but announcements current as this is written do not indicate that any complete plastic bodies have yet been built. It is not, of course, intended to put a body into production for some time, if at all. This will depend, to some extent at least, upon the success or failure in prolonged tests of bodies made on an experimental scale, and doubtless on costs, as compared with all-steel construction.

### Use of Multiple Moulds

Naturally, Ford engineers and others working on the development are well aware of the many obstacles still likely to be met and to be overcome if a feasible body is to be evolved. At present the plan calls for reducing the time per piece moulded by using multiple moulds placed one above the other in the same press. Moulds stacked three high have been tried and found to work, and it is thought that a stack twice this height can be made to do likewise. With such an arrangement, if the cycle be six minutes long the average rate of production would be one panel a minute, believed to be near enough to the rate with drawn metal panels to meet requirements. By stacking moulds, of course, fewer large presses will be needed, but the cost of multiple moulds still remains. There is also the problem of applying, perhaps, several inserts per panel, and this may lengthen the cycle considerably. Use of preforms made to fit the moulds will, of course, facilitate rapid loading of the moulds.

Mouldings of a panel for a rear deck covering the luggage compartment of a conventional Ford car have been produced in a press of 1,000 tons capacity. In these, the moulding pressure is said to have been about 1,600 lb. per sq. in. The panels are reported to have given a good account of themselves in service and are said to be little injured by a blow from an axe, used for demonstration purposes, although a similar blow on the much thinner steel panel normally used badly dents and cuts the steel. This is considered indicative of ample impact strength and of a lack of fragility likely to promote safety. It is also pointed out that plastic panels are good insulators against the passage of heat and sound and that this may save in the use of insulating materials now required with steel bodies.

Much is made by most writers on plastics of their inherent colour and of the saving which this may involve in finishing. (Mr. Walker, incidentally, stresses this point as well as transparency—for windows—as among the benefits of a plastic body without much thought apparently as to the cost of brightly coloured or transparent plastics or their suitability from several angles.) Ford investigators are not counting much on such benefits, although they know their utility on certain small mouldings used extensively for trim in current Ford car interiors. The natural colour of the plastic may possibly be utilized when an all-black body is wanted, but it is realized that phenolic plastic colours are not light-fast and that it would be hard to match them, anyway in many moulded parts. Also, some exposed metal appears inevitable, and since it will require an applied finish the plan is to apply a finish to the complete assembly, much as for a steel body.

The possibility of a revolution in body construction is one which would not, perhaps, be too great an obstacle for a company with Ford resources to overcome, providing, of course, costs as low, or nearly as low, as for a steel body could be realized, and also providing that the body is proved to be satisfactory from a service angle and is acceptable to the buying public in other respects. Ford has plenty of keen competition and is unlikely to contemplate seriously the use of a body at a higher cost than that of the steel type unless there are compensating gains which the public is willing to pay for at a premium.

It is quite evident, however, that Ford intends to make enough plastic bodies on an experimental scale to either demonstrate their worth or to learn that such bodies are not capable of production in a form and at a price which warrants the company in proceeding with quantity manufacture. It is certain that an enormous investment in plant (probably for making the plastic, producing preforms in quantities and moulding them on a prodigious scale) would be needed to manufacture bodies at the rate of thousands a day now attained with steel bodies. But it seems likely that Ford would spend the money if convinced that it would accomplish his objective.

### Availability of Raw Materials

The mere matter of supplying plastic in the great quantities that would be needed is one to give pause. Phenol is not especially plentiful but is being made synthetically by others in large, yet limited quantities. Although Government bureaux are working on other plastics, such as the lignin type, for which ample raw materials are available, the utility of such plastics for large moulded parts is yet to be demonstrated. Ford had been moulding tractor seats from the same plastic now being tried for body panels, and these seats are known to have withstood severe weathering tests for long periods. So the Ford plastic gives promise of being suitable as far as yet judged. But the questions of cost and availability in adequate quantities remain open and unanswered, as far as is yet known.

In view of all this, one must conclude that Mr. Walker's dream still lacks fulfilment by a large margin, for it included plastic substitutes for glass parts of the conventional body and an unpainted structure which appears to be too uncertain even for Mr. Ford to undertake. That the clear transparent plastics cost from about 50 cents to around $1.00 a pound, and that they are easily scratched and not all suitable for weather exposure, appears not to concern Mr. Walker greatly. He sees also great prospects for automatic moulding, but seems to care little that it is limited to small parts weighing only a few ounces and made from powdered plastic quite lacking in the properties needed in a plastic suitable for large body parts.

Nevertheless, it is easy to be enthusiastic about plastics, for they have made for themselves an enviable place in this modern world. Still, it seems to be much easier for the Walkers to create their plastic bodies (on paper) than it does for the Fords to make them in substantial plastics. Hence the writer's applause goes Fordward; yet he concedes that the world may need some Walkers too.

# ADHESIVES and CEMENTS

*In our January, February and March issues, the author completed the sections under phenolic and urea-formaldehyde resins and nitrocellulose and cellulose acetate cements. In these pages he deals with those of the polyvinyl, polystyrol and glyptal types*

By
E. E. HALLS

### Polyvinyl Materials

POLYVINYL esters, such as acetate or a mixture of the acetate and chloride, are used as jointing adhesives when dissolved in suitable solvents, such as methyl alcohol with isobutyl phthalate as plasticizer. These adhesives have been recommended for securing abrasive or abrasive paper to steel discs for grinding wheels. They can be used for building up laminæ of nitrocellulose or cellulose-acetate sheets, or for interleaving transparent plastic between glass, or for directly securing glass sheets. For this purpose, the adhesive has the merits of being completely colourless, transparent to visible and to ultra-violet light, non-yellowing, resistant to heat and to freezing and excellently adherent. For shatterproof glass, a cellulose derivative is usually necessary to impart the requisite strength. Polyvinyl acetate or butyrate can serve as adhesive, alcohol or ethyl acetate as solvent, and with cellulose acetate as the sandwich layer, triacetin or a tartaric ester as a good plasticizer, preferably appearing in both the adhesive and the film layer. Nitrocellulose as the sandwich tends to yellow, a disadvantage that can be diminished by using a mixed material of polyvinyl ester plus nitrocellulose. A typical liquid adhesive formula is as under:—

| | |
|---|---|
| Polyvinyl ester resin ... | 40 parts by weight |
| Cellulose ester ... ... | 4-12 parts by weight |
| Volatile solvent ... ... | 60 parts by weight |

Dry glues contain such constituents as polyvinyl acetate, ethyl acetanilide and cellulose acetate or ethyl cellulose. The equivalent of the shellac-coated tissues known as "photo-mounting papers" are available having polyvinyl-acetate coatings. One of these, of overall thickness 0.0025/0.0030 in., comprising a transparent hydrated paper of the "glassine" type coated both sides with the polyvinyl acetate, proved satisfactory in the terminal-fixing problem discussed earlier. The fixing conditions comprised assembly, tightening of bolts, baking for 10 minutes in an oven heated to 150 degrees C., partial cooling, final tightening and cooling. Shawinigan, Ltd., markets two ranges of compounds of this nature suitable for metal-to-metal or non-metal joints.

Known by the trade names of Gelvas and Alvars, they are based upon polymerized vinyl-acetate resin. Gelvas are said to give most outstanding results as adhesives for the purposes under discussion.

Gelva is manufactured in the following standard range of viscosities, in centipoises, of a solution in benzene containing the molecular weight of the monomer (86 gr.) per litre, measured at 20 degrees C., namely, 1.5, 2.5, 7, 15, 25, 45 and 60 cp. All are good adhesives and the choice depends to a considerable extent on the method of application; that is, whether applied dry by heat alone, or in solution, followed by drying and heating.

### Physical Strength of Gelvas

One of the outstanding characteristics of the compound is its remarkable power of adhesion to porous and non-porous surfaces. The strength of the bond on a straight pull where various polished metals and glass were bonded without pressure was in excess of 1 ton/sq. in. (1.58 kg./sq. mm.). Bonds have actually been made so strong that conchoidal pieces were pulled out of plate glass without breaking the bond to a metal plug. This power of adhesion has made Gelva a useful adhesive in assembling safety-glass laminations.

Where a non-flexible bond is required between non-porous surfaces, Gelva can be use as a thermal cement. Temperatures approximately 20 degrees C. higher than the softening points given in Table 13 yield a satisfactory bond. Where a very strong bond is required on non-porous surfaces and slight flexibility is permitted, Gelva should be applied in solution to both surfaces and baked. The two surfaces are then moistened with solvent and immediately joined together with pressure. Gelva has the same refractive index as Pyrex glass and leaves no line of demarcation in assemblies of this material.

Table 11.—Characteristics of Glyptal Varnishes Used for Sealing Gaskets.

| Sample No. | 36 | 37 | 38 |
|---|---|---|---|
| Source | J | J | L |
| **Chemical:** | | | |
| Volatile Spirit (loss in weight, 3 hours at 110°C.), % | 40.0 | 50.0 | 70.0 |
| Total Solids, % | 60.0 | 50.0 | 30.0 |
| | 100.0 | 100.0 | 100.0 |
| **Physical:** | | | |
| Viscosity at 25°C., centipoises | 240 | 360 | 40 |
| Specific Gravity at 25°C. | 0.936 | 0.930 | 0.990 |
| Drying time in hours: | | | |
| Surface | 4 | 8 | 1½ |
| Hard | 24 | 24 | 24 |

Table 12.—Characteristics of Slow Drying Elastic Sealing Paints, Pigmented Synthetic Type.

| Sample No. | 39 | 40 | 41 |
|---|---|---|---|
| Source | J | J | M |
| Colour | Black | Red | Red |
| **Chemical:** | | | |
| Volatile Spirit (loss, 3 hours at 110°C.), % | 40.3 | 32.2 | 59.0 |
| Total Solids, % | 59.7 | 67.8 | 41.0 |
| | 100.0 | 100.0 | 100.0 |
| **Physical:** | | | |
| Viscosity at 25°C., centipoises | 240 | 220 | 1,200 |
| Specific Gravity at 25°C. | 1.023 | 1.188 | 1.050 |
| Drying time, hours: | | | |
| Surface | 4 | ⅝ | ¼ |
| Hard | 18 | 24 | 3 |

For bonding two porous surfaces, or a porous and a non-porous surface, Gelva in the form of a liquid adhesive is preferable. The best bonds are obtained by coating both surfaces, allowing to dry, then moistening with solvent and immediately joining under pressure. In some cases, such as labelling or sealing wrappers in automatic machinery, the bond is made by the application of heat and pressure, one of the surfaces having been previously coated with solution and dried.

In general, the low viscosity Gelvas are not permanent adhesives for porous surfaces, because their small molecular size permits a gradual penetration which eventually leaves a dry bond. On soluble surfaces such as celluloid, cellulose acetate, moisture-proof "Cellophane," Kodapak, etc., the solvent/non-solvent mixture must be one that does not have too active an effect on the soluble surface. For general use the mixtures in Table 14 by weight are suggested. Plasticizers may be added if flexibility be required, although this decreases the adhesion.

Gelva has been successfully used in the bonding of paper, leather, felt, cloth, cambric, wood, glass, porcelain, metals, plastics, "Cellophane," Kodapak, Sylphrap, Pliofilm, metallic foils, mica, stone, etc.

Table 13.—Physical Constants of the Gelvas.

| | |
|---|---|
| Specific Gravity at 20°C. | 1.19 |
| Refractive Index $n\frac{20}{d}$ | 1.467 |
| Dielectric Strength, Volt/mil. | 1,000 |
| Dielectric Constant at 30°C. | 2.7 |
| Coefficient Linear Expansion | 0.000086 |
| Water Absorption (A.S.T.M.) | 2.0 |
| Acid Value | Nil. |

Softening Point (Kraemer and Sarnov), Tensile Strength and Viscosity

| Gelva Grade | Soft. Pt., °C. | Tensile Strength, lb./sq. in. | Viscosity—Weight % Concentration of Toluene Solution at 2.5 poises |
|---|---|---|---|
| 1.5 | 65 | — | 55 |
| 2.5 | 81 | — | 45 |
| 7 | 106 | — | 32 |
| 15 | 131 | 5,000 | 25 |
| 25 | 151 | 5,000 | 20 |
| 45 | 183 | 5,000 | 17 |
| 60 | 196 | 5,000 | 14 |

Gelvas are soluble in common organic solvents such as methylated spirit (containing up to 40 per cent. water), benzene, toluene, esters, acetone and chlorinated hydrocarbons, but insoluble in petroleum-hydrocarbons, oil, turpentine, water, etc.

As plasticizers, the following give high flexibility and permanence and water resistance equal to Gelva alone, or better:—Triethylene glycol hexoate, quinone, diphenylmethane, diphenyl, benzyl benzoate, tributyrin, isoamyl phthalate. The common plasticizers may also be used, including tributyl phosphate, Santicizer E15, dimethyl cellosolve phthalate, dibutyl tartrate, diamyl phthalate, dibutyl phthalate, and many others.

The following non-plasticizing diluents improve the water resistance: DOWP2 and DOWP4. Gelvas are compatible in all proportions with nitrocellulose and are suitable for preparation of spirit lacquers, varnishes and enamels. They are excellent vehicles for aluminium and bronze powders, also as impregnating dopes for paper, cloth, felt, etc., and as stiffeners and agents to give grease resistance.

### Polystyrol Adhesives

The chief attribute of the polystyrols is low power factor at radio frequencies; moulding powders, sheet, rod and tube products have, therefore, claimed prior attention and relatively little development has been done on polystyrol cements and adhesives. However, they are used. The pure resin gives brittle films and is thus invariably plasticized with one of the arochlors, Sancticizers or similar products. Styrene is made by the dehydration of beta phenyl ethyl alcohol and is polymerized by exposure to light at ordinary temperatures and by heat. The time of polymerization ranges accordingly from a few months to a few hours, and the micelle size of the product varies accordingly. Correspondingly, so does the ease of dissolution in solvents and the viscosity of the polystyrene solutions so formed. For high-viscosity low-solid-content adhesives, the air-polymerized form is used; for high-solid-content low-viscosity solutions, the high-temperature polymer is resorted to. The temperature polymerization, of course, is effected in an autoclave, that is a closed pressure vessel.

Table 14.—Suggested Gelva Solutions for "Soluble" Surfaces such as Nitrocellulose, Cellulose Acetate, M.P. "Cellophane."

| Type | Fast Drying | Medium Drying | Slow Drying |
|---|---|---|---|
| Acetone | 75 | — | — |
| Ether | 25 | — | — |
| Methanol | — | 95 | — |
| VM. and P. Naphtha | — | 5 | — |
| Isobutyl Acetate | — | — | 50 |
| Xylol | — | — | 50 |
| Gelva 2.5 | 85 | 85 | 85 |
| or Gelva 7 | 60 | 60 | 60 |
| or Gelva 15 | 40 | 40 | 40 |

All values are parts by weight.

Typical adhesive solutions can be prepared to the data given in Table 15. They represent sealing solutions used for delicate electrical apparatus, as for moisture-proofing all junctions in telephone capsules; that is, between aluminium-alloy diaphragm and brass seating and between the waterproof membrane and the cover and case.

### Glyptal Varnish Adhesives

The glyptal varnishes, particularly, have been used for rendering gaskets oilproof. Cork and fibrous gaskets, such as Vellumoid and Eagloil, on flat or recessed seatings can be treated in this way. The elastic synthetic paints have proved invaluable for sealing metal-to-metal seatings to prevent the ingress of moisture. Air-drying glyptal oil varnishes are shown in Table 11, whilst pigmented elastic synthetic paints are given in Table 12. These are all designed to dry in so far as they give non-tacky surfaces, but retain flexibility and adhesion.

A synthetic covered by U.S. patent No. 1,925,903 and developed specifically for securing aluminium foil to leather or to paper cites the following varnish preparation: A mixture of 11.82 gm. linseed-oil fatty acids, 16.35 gm. tung oil and 22.53 gm. resin is heated rapidly in an aluminium vessel to 280 degrees C. It

Table 15.—Polystyrol Adhesive Solutions.

| Sample No. | 48 | 49 | 50 | 51 | 52 |
|---|---|---|---|---|---|
| Composition by Weight, %: | | | | | |
| Polystyrene Resin | | | | | |
| Air Polymer | 7.5 | 7.5 | 4.0 | — | — |
| 1500 Polymer | — | — | — | 25.0 | 25.0 |
| Coal Tar Benzene | 91.0 | — | 95.0 | 70.0 | 20.0 |
| Coal Tar Solvent Naphtha | — | 91.0 | — | — | 50.0 |
| Arochlor 1254 | 1.5 | 1.5 | 1.0 | 5.0 | 5.0 |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

is then cooled to 260-265 degrees C. and the following ingredients added with continuous stirring:—

| | |
|---|---|
| Phthalic anhydride ... ... | 32.68 gm. |
| Glycerine ... ... ... | 16.35 gm. |
| Ethylene glycol ... ... | 4.22 gm. |

The mixture is maintained at 200-220 degrees C. until clear and is then held at 250 degrees C. until a sample withdrawn solidifies in 40 secs. at 200 degrees C.; 11 gm. of this resin is dissolved in 11 gm. of acetone and 5 gm. dibutyl phthalate added. The resulting solution is blended with ½ sec. nitrocellulose solution to give adhesive and flexibility properties suiting the particular purpose in view.

### Sealing of Gaskets

Gaskets of cork or fibre are oil-proofed in the following manner. The metal components are thoroughly degreased with solvent naphtha, paying particular attention to the seatings. The latter are then given a generous, but even, layer of glyptal varnish (e.g., material No. 36, Table 11). The gasket is now placed in position, the two metal components placed together and the fixing screws or bolts inserted and tightened. The assembly is left to dry for 72 hours prior to oil filling, or (if oil filled prior to assembling the gasket) before tilting to bring oil into direct contact with the varnished junction.

The synthetic non-drying oil paints are very effective for sealing the seating surfaces of castings without the use of gaskets. In many cases small, automatic electrical-control units are fixed in boxes and sealed by virtue of the design of the latter, which are in two parts with seating surfaces and flanges for bolting them down. Synthetic-resin mouldings, light-alloy castings and zinc-alloy die-castings are all used as containers.

Often narrow, yet accurate, seating surfaces are entailed and gaskets of rubber, treated fibre or cork are undesirable, if not impossible of application. A waterproof, permanently elastic paint is simple to use and caters for slight inequalities at the junctions, whilst a selected Plasticine or elastic bituminous compound serves to fill slots of holes through which electrical leads or connections are taken.

The general finish on metal castings used for such purposes is black enamel, and a black sealing paint is appropriate; other simple colours can, however, readily be procured to suit different finishing schemes.

The sealing is performed upon final assembly; if grease contamination of the enamelled castings be suspected, the mating surfaces are wiped over with a cloth moistened in solvent naphtha. A generous coating of black sealing solution is brushed over the seating surfaces and allowed to flash-off for not more than 10 mins. The parts are carefully and accurately placed together and the fixing solution that exudes is carefully wiped off, if necessary, with a cloth very slightly damped with solvent naphtha. Finally, a neat coat of the sealing solution is brushed around the junction. Twenty-four hours are allowed for the drying-off of the solvent prior to packing for storage or shipment.

Air-tight seals on aluminium castings, using red synthetic sealing medium, were exposed to extended humidity conditions. Medium No. 41, Table 12, showed excellent performance under test for three months, with no loss of flexibility and adhesion. Medium No. 40 did not behave so well, hardening, becoming brittle in places, and losing adhesion.

*(To be continued.)*

## *EMBELLISHING THE RADIO CABINET*

*(Continued from page 68.)*

The writer has been anxiously awaiting the development of coloured plastic inlays into moulded cabinets. To take a simple example, a black moulded cabinet would be moulded with a circular recess into which could be slipped a circular disc of a contrasting colour, say, of transparent cast resin. The effect would doubtless be interesting and obviously a variety of designs could be employed. It is the lack of a really suitable adhesive to fix such a decoration in position that holds up such a development. It is a pity, for we can imagine the combination that could be employed—bars or studs of inlaid acetate or of acrylic or polystyrene resins with fascinating light transmitting and reflecting properties.

An even more interesting suggestion than colour contrast introduction is that colour contrast, brightness and apparent increased strength can be given to the cabinet by the application of metal decoration.

Such methods introduce new techniques, but the mechanical ability of the average high-class moulder should not be beyond them.

The various suggested methods may be classified roughly as follow:—

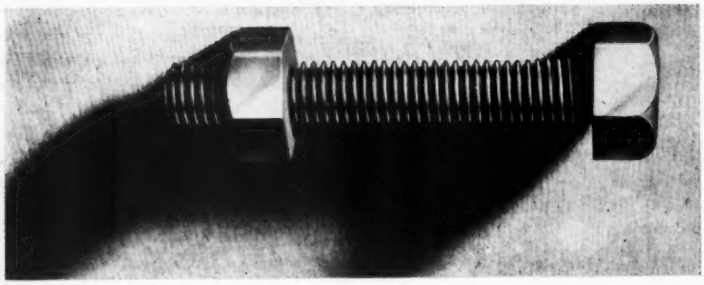
(1) The introduction of metal plates, strips, filigree work, etc., into the die prior to the introduction of the powder, so that the latter is moulded around the design which becomes one with finished moulding and lies exposed on the surface.

(2) The introduction of metal strip, copper, silver, anodized aluminium. As will be seen from the drawing on page 68 the cabinet is moulded with two channels, the metal strip being cemented therein or cemented and fixed from the rear. Much might be learned from a method such as the Cellon strip process now being used in aircraft production (see *Plastics*, July, 1940).

(3) Electroplating. The channels could be electroplated with chromium, rhodium, nickel, etc. Electroplating plastics has already been carried out fairly successfully, but the treatment of a large number of bulky objects, the largest proportion of whose surface must be protected against the electroplating, presents its own problems. Electroplating would, however, seem the most promising method.

(4) Metal spraying. The channels, the surface of which could be made rough in the mould, could be sprayed with most metals. Attempts so far to metallize plastics have attained some success. Polishing sprayed metal is normally possible.

(5) **Metal lacquers.** This covers suggestions such as (a) applying a phenolic or urea-resin lacquer, spraying with metal and then baking, and (b) application of a cellulose lacquer carrying metal powder. The main problem is that of strength of the bond.



# SCREW THREADS IN PLASTICS

## *The Need is Stressed for the Application of Sound Engineering Conceptions to the Design of Threaded Components in Plastics*

SCREWS, together with the corresponding female thread, constitute the most common means for permanent or temporary joining together of two or more components. In so far as plastics are concerned, the more these materials find application in machine components, electrical appliances and for general utility purposes, so will the provision of screw threads, both male and female, become of greater importance.

It must be recognized at the outset that the provision of a threaded joint is not to be considered as adventitious, but rather as a definite feature of design, for the most economical and foolproof solution of which, maximum collaboration must exist between mould designer and works manager.

It is proposed in the following account to consider present-day practice with respect to the provision of threads on moulded components and on laminated material. Both theory and practice will be discussed with the object of assisting both the designer and the practical man in the task of selecting the most suitable type of threaded joint.

In Table 1 are summarized the possible methods available. Somewhat naturally, the greatest appeal is vested in those systems in which the thread is formed directly through the moulding process, additional machining operations which tend to increase handling and production costs being thereby eliminated.

### Strength of Screw Threads

Before dealing in greater detail with the matter contained in Table 1, it may prove advantageous to consider briefly the mechanical theory of threads in plastics. The question which immediately comes to mind is: " Are there any fundamental differences with respect to strength and durability of threads produced by different methods in plastics? " It appears that the only work published in this connection is that of K. Mehdorn; this, unfortunately, was restricted to threads of 3 mm. and 5 mm. diam.

In Table 2 are presented the strength values for tensile loadings of an M3 thread (metric thread S1 form, 3 mm. external diam., 0.5 mm. pitch. This corresponds to a 5BA or 6BA thread, but possesses a finer pitch). It will be observed that the tensile load sustained by the thread lay between the calculated values for shear strength and bending strength.

Material S with wood-flour filler yields a markedly stronger thread than material $T_2$ containing a comminuted textile filler. So far as differences between cut (machined) and moulded threads are concerned, the figures yielded by the screw thread M3 (Fig. 1) and the screw thread M5 (Fig. 2, M5 equals metric thread S.I. form, 5 mm. external diameter 0.8 mm. pitch; this corresponds approximately to a 2BA or 1BA thread), are illuminating.

Strength data in these cases are assessed in relationship to the engaged depth of thread. In the case of M3, the strength of the cut thread is the lower, whereas for M5 the moulded threads have lower strength. Mehdorn advances the following explanation of this. In the case of threads cut by means of taps it is suggested that there is a tendency for a burr to be present on the cutting edge of the tap. Granted, in the case of plastics this is quickly removed when the tap is used, nevertheless, the first threads tend to be cut to oversize diameter, so that, in effect, they lie beyond the prescribed tolerances.

Unfortunately, Mehdorn omits, when advancing this hypothesis, to give production tolerances, nor does he give accurately the composition of the materials upon which his experiments were conducted. These omissions, together with the limited range of diameters examined, render his conclusions unconvincing.

In the case of moulded metric threads, no tolerance for external diameter is provided in the standard specifications. Some mould manufacturers provide sharp edges to the thread, instead of adopting a small land which, theoretically, should be equivalent to 0.108 pitch; i.e., in the case of M3 the land should be 0.054 mm. wide and, in the case of M5, 0.087 mm. wide.

It is important to observe that, in the case of the Whitworth or BA thread as used in this country, the threads have a rounded crest; therefore, the argument which follows will not apply.

### Moulded and Cut Threads

When moulding a sharp-crested metric thread of the type described, wear of the threaded mould insert will occur; in particular, the sharp edge being heavily loaded will tend to wear more rapidly than the remainder, thus the external diameter of the moulded thread will become smaller. Furthermore, the effect of employing such a design must be considered in relationship to the thermal expansivity of both the mould material and the plastic itself, whilst the shrinkage of the latter may also tend to exert an adverse influence.

Mehdorn concludes that the grinding burr present on taps for the M3 thread is, in relationship to profile size, greater than that on taps for the M5 thread; hence, the M3 thread cut by such a tap will be disproportionately weakened, so giving rise to the fact that the moulded M3 thread will, in practice, be stronger than the cut M3 thread. On the other hand, in the case of the moulded M5 thread, the notch effect of the sharp crests is more pronounced; the cut M5 thread will, therefore, be stronger.

In actual practice, the differences observed are so very slight that, for all normal purposes, the cut and moulded threads may be considered to possess the same strength.

Table 1.—General Comparison Between the Different Methods of Thread Production in Plastics.

| Method | Favourable features | Unfavourable features | Special points to observe | New ideas |
|---|---|---|---|---|
| Moulding .. .. .. | Part finished when leaving mould; cheap | Unscrewing operation; tolerances | Shape of thread owing to shrinking | Mechanical unscrewing; designs to avoid unscrewing |
| Moulding-in of inserts .. | Exact and strong threads | Higher costs; special placing methods | More space dislocation under pressure | Non-metallic inserts |
| Special inserts after moulding | Exact and strong threads; no risks in moulding | Higher costs | Special shape of mould pockets | — |
| MACHINING OPERATIONS | | | | |
| Single-point chasing tools .. | Exact and accurate threads | High abrasive action of plastics | Removing of skin; small lot production | Hard-metal-tip or diamond tools |
| Multiple-point chasing tools | Exact and accurate threads | High cost of tool | Removing of skin; mass production | Special hard-metal-tipped tools |
| Milling .. .. .. .. | Exact and accurate threads | High cost of tool | Mass production | — |
| Taps and dies .. .. .. | — | Possible inaccuracies owing to grinding burr and wear | Tolerances of moulded holes; tap drill sizes | Hard-metal-tipped taps |
| Self-tapping screws .. .. | No special tapping operation | — | Drill sizes | — |
| Hammer-screws .. .. | Quick driving method | Cannot be loosened | — | — |

In this regard the influence of working and moulding tolerances must be considered. If the screw threads in both components possess tolerances which might be graded as lying between medium and coarse limits, variations of up to 31 per cent. will occur in shear strength values, and up to 8 per cent. in bending strength values; the combined variation will be in the order of 25 per cent.

This variation is much greater than any difference recorded for materials S and $T_2$ forming the subject of these tests. It is, furthermore, greater than that determined between cut and moulded threads. From Figs. 1 and 2 it will be seen that no linear relationship exists between strength of thread and engaged length of screw. Theoretically, this relationship would have been assumed. The strength curves are of the parabolic type; this may be explained by the fact that, with greater engaging depth, the full load is not carried by every screw thread; pitch errors may account for this.

Table 2.—Strength of Female Threads of 3 mm. diam. with Three Fully Engaged Threads; Height of Nut, 1.5 mm. (After Mehdorn.)

| Material | Designation | Shear strength, tons/sq. in. | Bending strength, tons/sq. in. | Female thread | | |
|---|---|---|---|---|---|---|
| | | | | Calculated shear strength, lb. | Calculated bending strength, lb. | Tensile strength measured, lb. |
| Phenol-resin with wood flour filler .. | Type S .. | 7.95 | 4.45 - 5.07 | 334 | 111 | 213 |
| Phenol-resin with chipped textile filler | Type T2 .. | 7.82 | 3.8 - 4.77 | 328 | 94.7 | 178 |

The strength of the female thread, or nut, can only be considered in relationship to that of the male component. For this reason, in Figs. 1 and 2 are introduced strength values for different kinds of bolt; these are represented by parallel lines. Some differences are obvious in the strength properties of the bolts, thus, for M3, the lowest strength figures are given by rolled-brass screws, whilst for M5 the lowest values are given by turned-brass screws.

It is usually desirable that the nut possess greater strength than the bolt, so that in the case of failure due to overload, the component of which the nut forms an integral part may be saved and the bolt alone replaced. Open brass nuts require only a very small engaging depth so that a nut height of 1.5 d (d=thread diam.) is generally satisfactory.

From these data it may be concluded that, for moulded threads in material S, a thread depth of 1.0 d suffices; for material $T_2$ the desirable thread depth would appear to be 1.5 d. However, for practical purposes the minimum depth of 2-3 d may be assumed. In the case of M5 the engaging depth may be less, but in this case, too, a length of 2-3 d is recommended. It may be interesting to observe here that, for screw bolts for light metals, an engaged length of 2.5 d is usual, and this figure would, as we say, appear to be quite acceptable for plastics.

It is generally desirable that the plastic component should emerge from the mould in the finished state, the only finishing process required being the removal of the flash. From this it would appear, therefore, that all screw threads should be formed during the moulding operation. Nevertheless, a number of factors must be taken into account if the results of such a procedure are to be successful; failure to provide for these factors will result in endless trouble.

Even if tolerance for any single dimension of a thread be not very exacting, it is certain that the sum total of dimensional variations will exert a great influence on the production of successfully mating screw components. Thus, pitch, pitch diameter, and angle of profile may, individually, possess wide tolerances, yet the very existence of these tolerances will call

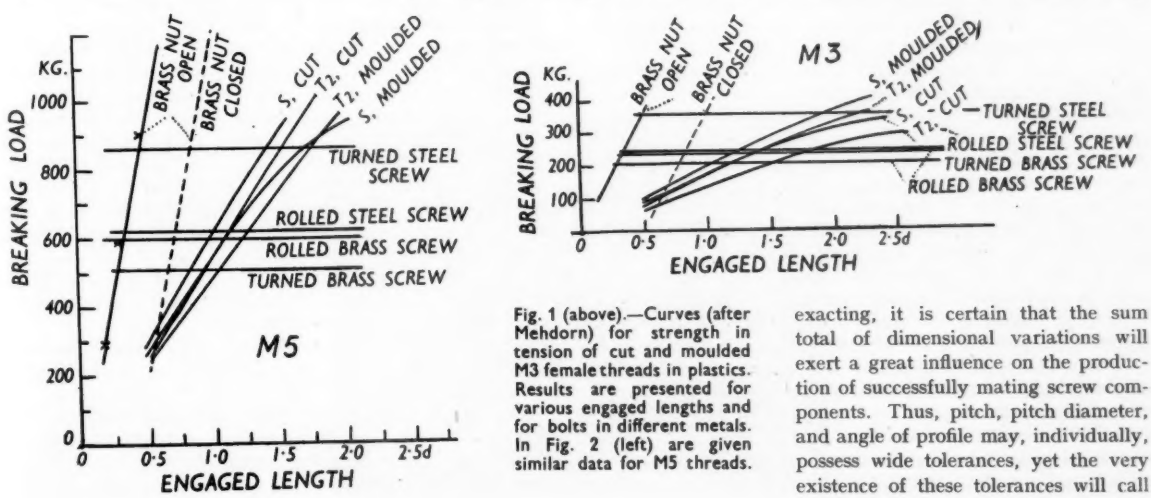



Fig. 1 (above).—Curves (after Mehdorn) for strength in tension of cut and moulded M3 female threads in plastics. Results are presented for various engaged lengths and for bolts in different metals. In Fig. 2 (left) are given similar data for M5 threads.

for greater skill in maintaining a balance between varying factors.

In practice, therefore, all threads provided in moulds for direct thread-moulding practice must necessarily be produced to very close limits, whilst circumstances dictate that tolerances must be different from those usually employed for screw work.

The measurement and control of such threads tends to be difficult as the usual screw gauges cannot always be employed. In determining dimensions and tolerances for thread components in moulds, it must be borne in mind that moulding takes place at an elevated temperature and that the thermal expansion of the steel and of the plastic material differ. These last two factors are subsidiary to an even more important variable, namely, shrinkage in the plastic employed. Particularly, the thread component in the mould should be designed to correspond as closely as possible to the maximum thread diameters finally desired; indeed, these values may be slightly exceeded in order to compensate for inevitable wear.

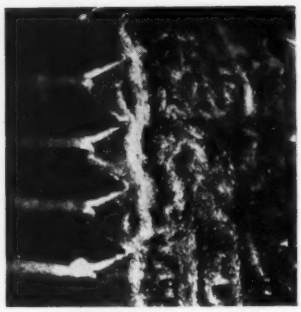


Fig. 3.—Photomicrograph of cross section of moulded thread (right side of illustration) in material $T_2$, containing textile filler. Note that filler particles have not entered the triangular thread profiles.

Frequently the use of a moulded thread may be favoured in those instances where the threaded part is clearly open to inspection or is readily visible in the assembled component. Such moulded threads have a smoother finish than a machined thread due to the fact that, at the surface, the concentration of filler material is reduced; this phenomenon was fully discussed in the November, 1940, issue of PLASTICS (page 257).

In Fig. 3 is reproduced the microstructure of the moulded thread in material $T_2$. It will be noticed that the particles of textile filler have not entered the triangular thread profiles. The strength of the thread is not seriously influenced because of this, as these fillers tend to increase only the impact-bending strength of the material, a property not affecting the strength of the thread itself.

*(To be continued)*

## BRITISH STANDARDS IN WAR-TIME

Some months before the outbreak of war the British Standards Institution, which is the recognized centre for the promulgation of all national British Standards, offered H.M. Government the services of the Institution, as a complete unit, in the national emergency. This offer, which was sent to the Board of Trade through whom the B.S.I. receives its Government grant, was most cordially received.

On the outbreak of war the B.S.I. realized that its peacetime procedure was inadequate to deal effectively with the demands imposed by the changed conditions, and especially by the need for rapid action. A number of small executive committees were therefore set up for the various sections of its work, these being made fully responsible for the preparation of any War Emergency Specifications the Institution might be called upon to undertake. Under this emergency procedure the executive committees were given authority to restrict the usual wide consultation of industry to those interests directly concerned, and the reduction of the time usually given for comment on draft standards.

Government Departments are employing the B.S.I. machinery for the preparation, co-ordination and promulgation of War Emergency Specifications to meet their several requirements, that policy being adopted because of the great experience of the Institution in this field and because it provides a most effective liaison between them and almost all branches of British industry.

The B.S.I. is invited to send a representative to appropriate meetings of the Materials Committee of the Production Executive, which is representative of all Government Departments, the Central Priority Department acting as the liaison between that Committee and the Institution. This has brought the B.S.I. in close contact with the increasing number of Departments working to specifications, and is thereby bringing about a considerable measure of co-ordination in their preparation and issue.

The B.S.I., in collaboration with the appropriate branches of industry, has been entrusted with the task of making recommendations in the first instance to the above Economy Committees in connection with tinplate containers. The work is being extended to cover packaging generally, and has involved already the formation of more than 80 committees.

A further example of the employment of the B.S.I. by the Ministry in effecting saving of material is the issue of a War Emergency Specification for Bolts and Nuts with smaller heads, which, it is estimated, will save many thousands of tons of steel a year.

At the request of the Ministry of Home Security a special series of specifications (about 50 in number at present) has been issued covering many aspects of A.R.P. work.

In connection with exemption from the Purchase Tax the B.S.I. has provided H.M. Government with definitions which give the dividing line between babies', children's and adults' clothing and made recommendations for protective boots designed for use by miners, quarrymen or moulders. Recommendations have also been made in connection with the Limitation of Supplies Order.

The experience of the B.S.I. is also being drawn upon in several directions through the good offices of the Central Priority Department, where the preparation and issue of British Standards may not necessarily follow.

Besides all this the Institution, in response to direct requests from industry, has prepared and issued a number of War Emergency Specifications to meet the special conditions resulting from the restriction in the supply of materials, and the demands for new and revised standards to meet these contingencies are increasing.

This war work has in no way prevented the B.S.I. from maintaining its usual close relationship with the Dominions standardizing bodies, which have been kept in close touch with these developments.

Moreover, the B.S.I. Committee in the Argentine Republic, which is working in close collaboration with the IRAM, the Argentine national standards organization, is receiving increased recognition as its work is seen to be of real value to British export trade. British engineers and traders in the Argentine are to a greater degree giving practical support to the work of the Committee, and manufacturers in Great Britain have, by a far-sighted policy of financial support, made that work possible. British Standards, through the work of this Committee, are receiving the same consideration at the hands of the IRAM in the drawing up of Argentine standard specifications as the standards of other nations.

The B.S.I., with the help of the British Council and of industry, is also engaged in compiling a number of technical handbooks dealing with British industrial practice. The books are to be published in Spanish and Turkish, and should do much to familiarize engineers and students in Turkey and the Spanish-speaking countries with British methods.

Above: Insulating frame of injection-moulded white opaque Lustron.

Below: The Philco refrigerator with frame and door in place.

Above: Transparent evaporator door of polystyrene on the new Philco.

# BELOW ZERO with POLYSTYRENE

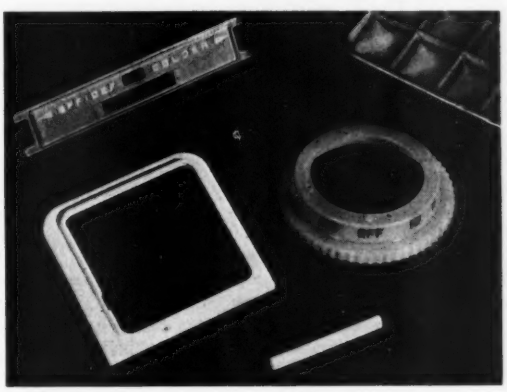
IT is only in the last five years or so that plastics have made an appearance in the domestic refrigerator, but in that time the progress has been marked. The adoption of plastics by engineers in this industry is, no doubt, due to the realization that the materials are relatively strong, are themselves heat insulators of a high order, are non-rusting in humid atmospheres, that some are exceptionally water-resistant and can be, transparent or coloured, useful aids in making the refrigerating apparatus of considerable æsthetic value. Finally, the qualities of hardness and high polish make them easy to keep clean. Truly, a combination of qualities sought by both manufacturer and housewife.

In reporting the life story, so to speak, of refrigerators as they affect plastics, we have noted in the pages of *Plastics* the coming of moulded ice-holders, and more latterly refrigerator window frames and rails for the industrial type. We are now able to report further progress in a plastic which we believe has not yet been so employed. The Monsanto Chemical Co., of Springfield, Mass., U.S.A., sends us the following notes regarding the new machine made by the Philco Corporation, which employs Lustron, a polystyrene resin made by Monsanto.

The insulating frame seen above is in pure white and is stated to be the largest piece ever injection moulded. Colour and finish are inherent and the polystyrene is tough and strong, even at low temperatures, and neither harsh cleaning, food acids, or prolonged exposure to moisture can destroy its beauty.

In the same Philco refrigerator of large size, the polystyrene Lustron is again used for the manufacture of the evaporator door. Here, however, the moulding is made from the transparent variety, an interesting feature which makes the frost of the freezing unit a part of the design, since the back of the door is quickly covered with sparkling frost in crisp contrast to the blue of the metal bands. This is a typically American bright thought.

The G.E.C. is also adopting polystyrene for its refrigerators. The four moulded parts shown in the lowest photograph are good examples. The round serrated piece is mounted with the flat moulding to form a unique indicator dial. The frame and rod are used in a separate compartment, where butter is kept at the degree of firmness required.



One point regarding polystyrene is of great importance. We have here one of the most expensive of plastics, yet, in spite of its price, its use is extending. Truly we can re-echo the hope that industry will consider properties first when real value is seen.

# World's Industry

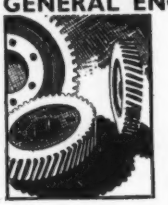
## MOTORS

**Decorative plastics** for automobiles is the subject of a detailed account by W. J. McCartney, of the Chrsyler Corporation, in the February issue of *Industrial Engineering Chemistry*. Particular attention is drawn to the replacement of cellulose acetate by the aceto-butyrate for those parts in close contact to lacquered and painted surfaces. The various plasticizers employed in cellulose acetobutyrate are without effect on the applied coatings, whilst those employed with the acetate tend slightly to volatilize and soften paint films. The acetobutyrate is employed for exterior fittings on account of its good weathering properties. The author notes that work is being carried out to improve the resistance of styrene polymers against chlorinated hydrocarbon solvents and suggests that if this be successful, an increased scope will be found for polystyrenes in automobile engineering. **Motorcycle frames** in which the latter (box type) are moulded in halves from phenol-formaldehyde impregnated paper, are the subject of patented design described by Christophe in a recent issue of *Motorrad*. The halves are riveted or bolted to give a structure equally as strong as the steel frame formerly used. **Total weight of plastics** used in a car is only a fraction of 1 per cent. of the weight of the vehicle, although it is stated that automobile manufacturers in U.S.A. are the biggest individual buyers of plastics. There is clearly room for further expansion. Those interested may mentally compare this figure with that for light alloys in automobiles, which is little in excess.

## AIRCRAFT

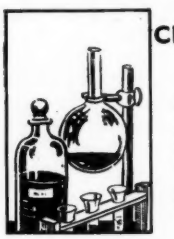
**Plastic fuselages**, consisting of moulded units formed over magnesium-alloy reinforcements are being worked on by an American aircraft manufacturer. The joint use of plastics and the ultra-light alloys achieves maximum strength and rigidity with minimum weight. **Avro Ansons** are now being made in Canada for the Royal Air Force, utilizing resin-impregnated plywood for fuselages and other structures. Presumably, these are the aircraft which are being made by the Vidal process, a note of which was published in the January, 1941, issue of *Plastics*. The Avro Anson is a trainer aircraft, and a Montreal report states that if the tests are successful 100 will be ordered immediately.

## GENERAL ENGINEERING



**Dekorit F**, a cast-phenol resin, is described by Drefer, in a recent issue of *Kunststaffe*, as being of value in all branches of the engineering industry. The mechanical properties of this material have been very fully investigated. Apart from such components as valve bodies in acid pumps, metering units for corrosive chemicals and similar parts, especial interest attaches to its use for pressure tubing. Pipes of 25-30 mm. bore and wall thickness of 10 mm. withstand a pressure of 150 atmos. before bursting. **Rolling stock** presents many potential fields of application for plastics. Gotusso, in a recent issue of *Materie Plastiche*, examines in detail the realized and possible uses of the synthetic resins in the Italian State Railways. He indicates their superiority to wood and cites folding tables as an interesting instance of successful replacement in this direction. For 900 coaches, 1,800 cover plates, 1,800 closet seats, 9,000 tables, 40,000 frames, 60,000 metres of moulding and 20,000 lamp stands were among the parts manufactured from plastics.

**Welding thermo-plastic resins** is critically described in an issue of *Deutsche Bergwerks Zeitung*. It is pointed out that the development of suitable techniques is necessitated by the increasing use of plastics for everyday structural purposes. In a sense, the process employed resembles that of autogenous welding in metals, the contacting faces being heated to melting point and subsequently pressed together. In place of the welding torch, a heated air or gas blast is used, the operating temperature being 230-270 degrees C. The gas or air is heated to the required temperature in a special burner, blown through the welding torch which is held 5-10 mm. away from the material being welded. Filler rods of the same composition as the plastic being worked are, if necessary, also used. The finished join is smoothed down by rubbing with the heated torch. Special reference is made to the value of the process in the construction and repair of chemical apparatus. **Laminated-plastic rollers** for use in continuous pickling plant for steel strip were described by Owsley in a late issue of *Iron Age*. Apart from the fact that such rollers cost no more than rubber-covered steel rolls used for the same purpose, they possess the advantage of being entirely resistant to the pickling solutions ordinarily employed, and cannot cause damage to the strip such as might occur if the rubber covering on a steel roll split. **Cable sheathing** is also discussed by Pallas in a recent issue of *Wörme*. Comparisons are made between the insulating properties of common lead-sheathed cables and the plastic-sheathed material, and the respective limitations of each type is defined. **Zellon masks** for operators in underground cable-junction boxes are commented upon in a further issue of *E.T.Z.* Light weight, easy shaping into the required form and non-splintering properties, are qualities of the material which commend themselves for this purpose.



## CHEMICAL

**Haveg 50**, a phenolic resin of a new type, is finding increased applications for chemical plant in U.S.A. This resin is resistant to hot solutions of potassium or sodium hydroxide and the impact strength is said to be high, and, using external supports, durable cylindrical tanks up to 6 ft. in diameter and rectangular tanks up to 10 ft. long have been fabricated. **Sieves and filters** fabricated from thermo softening resins are referred to by Ivers in *Chemische Apparatur* as having achieved satisfactory results. Pierced or woven sheet is used, the former being capable of taking a mesh 0.5 mm. in diameter for a sheet thickness of 0.4 mm. **Neoprene packing** for heavy-duty pumps and valves has shown itself of value for hydrogen and nitrogen up to pressures of the order of 77 atmos. A life of 10 months was obtained, as against a few weeks for materials formerly used. **Pigments for the synthetic resins** selected at one time on largely empirical bases are likely to become the focus of increased fundamental research as the field of

# ...mploys Plastics

application of plastics broadens. Thus, in U.S.P.2122270, the phenol-formaldehyde condensation is carried out in the pressure of calcium hydroxide and carbonate, and lactic acid. On removal of the water produced, precipitation of calcium lactate occurs. **Washable water paint** from the condensation product of formaldehyde at 2-4-6 triamino, 1-3-5 triazine, is described in E.P.480316. Lithophone of low zinc-oxide content is employed as a purifier and pigment. **Highly halogenated phthalocyanine** for colouring urea resins is suggested in E.P.490005. The copper compound of hexadecachlorophthalacyanine is stated to give a powerful green colour in concentration of 0.01 per cent.

## ELECTRICAL

**Light metal substitution** for copper in power-transmission lines has presented a new opportunity for the employment of plastics. Where junctions must be effected between copper leads and aluminium cables, the danger exists of electrolytic corrosion and, consequently, of the destruction of the aluminium resulting. By embedding the junction in a weather resistant plastic, both air and moisture may be excluded. This and other advantages of the use of plastics for such purposes are detailed by Perlick in a recent issue of *E.T.Z.* The use of synthetic-resin base lacquers for protecting the steel pylons is also considered.

## TEXTILES

**The role of plastics in wearing apparel** is summarized by Bunn in a recent number of *Chemistry and Chemical Engineering* (News Edition). The limitations of casein are considered, the current application of the thermo-setting resins noted, and the vast scope offered by the thermo-plastic materials by reason of their capacity for being produced in highly coloured forms. Among the novel items listed is braided glass fibre coated with cellulose acetate for women's shoes. Vinylite aprons, and transparent umbrellas and raincoats in the same material, offer the joint advantages of being waterproof, easily cleaned, mechanically strong and long lasting. Stiff shirt fronts are also produced in vinylite. The Vinyon bathing suit appears to offer great promise. Particularly interesting is the reference to Bakelite polystyrene of high refractive index for imitation jewellery. **Viscose and similar fibres** have a novel use, which is described in DRP.679334. Staple fibre is suspended in water containing small additions of a suitable adhesive or bond, such as methylcellulose or tragacanth (0.05 gm. per litre), and worked up without further processing into paper.

## SHIPBUILDING

**Warship cable insulation** is discussed by Breitonstein in a further issue of *E.T.Z.* The value of weight reduction is stressed, hence the replacement of lead sheathing by non-metallic materials of adequate strength and equally watertight. One instance cited refers to sheathing consisting of a mixture of Buna N, or Perbunan, with Plexigum and appropriate plasticizers, accelerators and fillers. It is pointed out that the Buna addition confers the ability to vulcanize the mass, good compression strength under heat being then obtained. By itself, the thermo-plastic constituent is too sensitive to loads at elevated temperature. The P.C.U. mixture withstood the proof test at 100 degrees C. for 70 days. **Shipbuilding,** an industry hitherto only lightly touched by the plastics and light metals, promises some post-war surprises if the expectation of Achilles and Mehdorn at Essen are realized. These workers, in a paper before the Schippbantechnisschen Gesellschaft, referred at length to the high corrosion resistance, light weight, structural stability and water-resisting powers of many of the thermo-hardening resins. Quite apart from such purposes as panelling and furniture the use of plastic hand-rails in place of those of brass is suggested, whilst safety rails and grilles assembled from extruded rod are also noted. The heat-insulating properties of the materials has been turned to advantage in the engine-room, where ventilator ducts and steam-pipe packing or casing has been fabricated from them.

## MISCELLANEOUS

**Foils and strips of polythene resin** have been manufactured by a newly developed process of rolling. The mill employed consists of two rolls, one of which is maintained cold, whilst the other is heated to the softening point of the resin. The product, after being reduced to the desired gauge, is slit longitudinally and stripped from the hot roll. A further interesting development for the preparation of very thin fibres consists in spreading the resin over the surface of a heated liquid of suitably high boiling point, the resultant pellicle being lifted after the liquid has coated. Mercury is suggested as a suitable fluid. For either of these processes, it is stated that polymers of molecular weight above 4,000, and preferably in the order of 6,000, be employed in order that sufficiently tough fibres be formed. **Potato flour** is the basis of a further plastic of vegetable origin that is reported to have been developed in Holland and the product is to be made available in both the opaque and transparent forms. It lends itself to all the usual machining operations and reacts well to the usual dyes and pigments. **Polish plastic output** has a melancholy interest attached to it. The output in 1937 is said to have reached about 300 tons per annum. This figure is significant in view of legislation passed just before German occupation to the effect that, in the rubber industry in Poland, for every 100 kg. of rubber imported manufacturers were to use 1.5 kg. of synthetic rubber. In this way it was hoped to stimulate the development of a domestic synthetic-rubber industry. **Pavement lights,** consisting of coloured plastic screens over sunk neon-strip lights, are being experimented with at Little Rock, Arkansas. The resistance to shock and abrasion of the plastic used should provide interesting data when tested out in the field. Lustron polystyrene plastic is used for the Lumitile structural block, consisting of a hollow moulding of the resin. **Vinidur** (polyvinyl chloride), for ventilating ducts up to 2 ft. 6 ins. diameter, has been found highly successful. **Vegetable waste** of various types and how it can be profitably utilized has attracted increased attention during the past few years. Now, in addition to coffee-bean products, a process has been described for utilizing lemon peel, from which, after removal of resinous matter, the pectin is extracted and treated with formaldehyde.

# Inquiries and Answers

*(In Which is Included General Correspondence)*

*IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. It is understood that the submission of a problem to the Editor permits its publication in this journal.*

### Fancy Goods Manufacturers

As a reader of *Plastics* I beg to ask you whether you could put me on some manufacturers of injection-moulded or other kind of plastic parts for the manufacture of fancy necklets, such as leaves, flowers, ornaments, etc. Further, I should be interested to get in touch with a manufacturer who could supply me with plastic chains or at least single chain-links (small round or oval rings) which I can put together.

London. A. SCHICK.

[EDITOR'S NOTE.—Among injection moulders are the following: Injection Moulders, Ltd., Thos. de la Rue, Ltd., Messrs. Fraser and Glass, Messrs. Runfield and Barstow, Insulation, Ltd., Bettix, Ltd., Ebonestos, Ltd., Prestware, Ltd., etc. Unfortunately, owing to Censorship we are unable to give addresses during wartime, but the inquirer can find them in the telephone directory. Alternatively, we will forward letters.

The reader should also realize that unless the manufactures are for export it is unlikely that raw material will be available for fancy goods.

### Ball Floats for Cisterns

On page 47 of the March issue of your journal *Plastics* you give details of a moulded ball float for cisterns, and we have noted your remarks.

For your information we should like to bring before you the fact that we have now been making float mouldings for approximately two years on behalf of Associated Builders Merchants, Ltd., and for your inspection we are sending you, under separate cover, a float moulding such as we are manufacturing.

The float in question has many good points, amongst these being that it is standardized and therefore interchangeable not only with other floats of the same design, but with copper floats. In addition, the float is adjustable to height by means of the movable slide and locking device and, from memory, the float which we make is appreciably lighter than the one which you have illustrated; possibly you have the sample which was photographed and could confirm our statement.

In conclusion, we would state that we have Associated Builders Merchants, Ltd.'s full permission to give the details mentioned above. BIRKBYS, LTD.

[EDITOR'S NOTE.—The float on the left of the photograph is that made by Birkbys, Ltd.; that on the right is by R. Cartwright and Co., Ltd., mentioned in our March issue. Avoiding invidious comparisons, we may congratulate both concerns on doing excellent jobs.]

### High Temperature Cements

I have been reading with interest the valuable articles you have published in *Plastics* on the subject of "Adhesives and Cements" and should like to ask if there exists an adhesive which will stand up to temperatures of 200-250 degrees C.? Such a material would be extremely useful for low-temperature furnace work. J.S.T.

[EDITOR'S NOTE.—We cannot believe that any organic adhesive or cement would be suitable at these temperatures for prolonged use. The thermo-plastic materials are out of the question, even if heavily loaded. Softening points for these can be as low as 60 degrees C., while the highest is about 125 degrees C. for certain polystyrenes and ethylcellulose. While this softening point can be raised considerably by incorporating mineral matter such as metal powder, asbestos, silica dust, etc., it must be remembered that the adhesive properties diminish rapidly with increase in temperature. Complete decomposition begins at various temperatures. Seemingly the only possible adhesives are the thermo-setting resins. There is no softening point and phenol-formaldehyde resins withstand fairly high temperatures before charring. Filled with minerals (e.g., asbestos) they can withstand a temperature as high as 220 degrees C., but it is difficult to believe that the adhesive properties of such a mixture would be as good as a non-filled resin.]

### Isoflex Insulation

I refer to the letter from Expanded Rubber Co., Ltd., in your February issue, and wish to give the following facts without comment.

(1) The figures given by B.X. Plastics, Ltd., were taken from The Department of Scientific and Industrial Research Report No. 35 dated 1929—an official publication on experiments made at the National Physical Laboratory by Dr. Ezer Griffiths, D.Sc., F.R.S.

(2) In that report expanded rubber and ebonite are mentioned as general terms describing materials, and not as proprietary articles.

(3) In the February issue of *Modern Refrigeration*, Dr. Ezer Griffiths publishes an up-to-date summary of the position in which the figures given in Report No. 35 are confirmed with the addition of a conductivity of 0.19 B.T.U. for expanded ebonite which had already been pointed out to us as an improvement made by Expanded Rubber Co. and duly given publicity by us in our letter in your February issue. The same remarks apply in the case of the article appearing in *British Plastics*, January issue. T. L. BIRRELL,

London. Director, B.X. Plastics, Ltd.

# PRODUCTION NEWS

## Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

**COFFEE PLASTICS.**—The rumours heard on this side of the Atlantic of the proposed large-scale use of coffee as the raw material for plastic manufacture has recently been confirmed in an American journal. A process has now been developed by a Mr. H. S. Polin for converting green coffee beans into a moulding composition. This is called Caffelite, to be manufactured by the Caffelite Corporation, and three plants are being built to exploit the process and utilize 50,000 bags of coffee beans a year. By 1942 it is hoped that manufacture will expand so as to use 5,000,000 bags a year. It is not quite clear why coffee is suitable, but no doubt there are amino bodies and aldehydes therein which provide a suitable foundation. If the process will put an end to the iniquitous burning of surplus coffee carried out in recent years, the world will be pleased.

**FOREST PRODUCTS.**—The utilization of forestry materials and wastes grows apace and the Forest Products Laboratory of the U.S.A. has given some indication of new plastics to be developed therefrom.

Comparatively simple in operation, reasonably inexpensive, and of apparent application in the bending of wood and in the production of cheap plastics and moulded articles, the new treatment is a by-product of the Laboratory's research on the chemical seasoning of refractory woods.

During the course of seasoning experiments, it was found that oak which had been soaked in a concentrated solution of urea and then dried became plastic and capable of being bent, twisted and compressed when a temperature approximately 212 degrees F. was reached and while the wood was still in the dry condition. The wood retained its plasticity while at or above the critical temperature and resumed its normal hardness and rigidity when cooled.

In addition, it was found that urea-impregnated wood chips or sawdust, when subjected to elevated temperatures and pressures, could be compressed to a density approaching that of basic wood fibre, and that in becoming self-bonding with the urea lignin produced by the treatment they form a material of true thermo-plastic properties.

Although the new process apparently has wide possible application in wood bending and in the production of cheap plastics, only research effort on exploring fundamentals of the treatment is at present being pursued.

**PLASTICS IN INDIA.**—A recent issue of *The Times of India* discloses that the possibilities of utilizing plastics have been examined by a sub-committee of the Board of Scientific and Industrial Research. Dr. S. S. Bhatnagar, Dr. H. K. Sen, Mr. M. N. Goswami, Dr. Habib Hassan, and Dr. J. C. Ghosh, members of the sub-committee, have collected the necessary material on the production of resins from various raw materials in India, such as lac, coal, molasses, coffee beans and oil. The committee has also favoured the utilization of oil plastics for producing telephone parts, as they are considered as good as the phenolic type. The Board has granted a sum of Rs. 20,000 to pursue the investigations.

Inquiries show that the main difficulty in the production of synthetic resins of the "bakelite" type is India's dependence on imported moulding powders. As these are prepared from phenol-formaldehyde synthetic resin, the question of producing phenol-cresol and formaldehyde on an extensive scale is being pursued. Wood flour is another important component of moulding powders, and the utilization of Indian timber for this purpose is being investigated. The Indian Lac Research Institute has also studied this problem and has developed two kinds of shellac moulding powders, one suitable for press moulding, the other for extrusion moulding.

**CONCENTRATED INDUSTRY.**—The new scheme for the concentration of industry in war-time, which is designed to make the most effective use of labour and materials available, was discussed by Captain Lyttelton last month in the House of Commons. By it some factories will be closed down for the duration of the war, manufacture being concentrated in a smaller number so that release of more workers will be possible.

Dealing with the manufacturing side of the scheme, he hinted that the industries first to be affected would be hosiery, toilet preparations, sports goods, linoleum, gloves, lace, umbrellas, glass, pottery, toys, plastic goods, photography, cutlery, carpets, fountain pens.

He made it clear that his proposal was purely a war-time measure. It was dictated by necessity and did not seek to found a new order in the industries affected. There was no intention of reducing the number of small firms or to force them into the arms of combines.

"I am prepared to give an absolute pledge," he said, "that where the size of the firm is so small that the dislocation caused would be out of proportion to the advantages gained by concentration, the Government will not touch it."

Closed-down firms must be given every opportunity to regain their trade after the war. Their revival would be helped by the enormous demand for goods that would be bound to occur then.

**VULCANIZED FIBRE.**—The original edition of the B.S. specification for vulcanized fibre for electrical purposes, published in 1926, covered sheets, rods and tubes. The 1936 revision dealt with sheets only and a new specification for rods and tubes is now about to be issued as B.S.934-1940. The specification is based on the results of comprehensive tests carried out by the Electrical Research Association on representative vulcanized fibre (natural colour) rods and tubes of quality suitable for electrical purposes. Limiting values are prescribed for various properties and methods of test are described.

Copies of this British Standard can be obtained from the British Standards Institution, 28, Victoria Street, London, S.W.1, price 2s. 3d. post included.

**PLASTICS CONTROL.**—We have received from Mr. L. P. P. Merriam, Controller of Plastics, the following notes regarding steel and plastics machinery supply.

Arrangements have now been made whereby authority has been given to this Control to issue licences to firms engaged in the plastics industry for the acquisition of steel for the purposes detailed below:—

1. New buildings and extensions.
2. Repairs and maintenance of buildings.
3. New plant and machinery.
4. Repairs to plant and machinery.
5. Jigs and moulds.

Owing to the necessity of conserving steel for essential purposes specific

Government contract numbers must be given in support of all applications, together with any other relevant information which will facilitate investigation.

Licences for high-speed steels and cast iron will not be issued by this Control, but applications should be sent to this address in the first instance, so that if approved, appropriate recommendations may be made to the department of the Iron and Steel Control, from which the licences will be issued.

Applications for machinery licences to acquire plastic machinery and plant (Class 37) Schedule to the Machinery and Plant (Control) (No. 2) Order, 1940, may, until further notice, also be sent to this Control. Licences covering such applications as are approved will be issued as hitherto by the Industrial Supplies Department (Machinery Licences Division), Board of Trade, 25, Southampton Buildings, Chancery Lane, London, W.C.2.

An application for a machinery licence must be accompanied by an application for an authorization to acquire the steel necessary for the manufacture of the machinery.

**NYLON DEVELOPMENT.**—For the 28th ordinary general meeting of Courtaulds, Ltd., Mr. Samuel Courtauld issued a statement to the stockholders in which he mentioned the progress made in the two plastic materials the company's subsidiaries are producing. British Cellophane, Ltd., he said, has had a good year, but it was particularly unlucky in the date of the war, for it had just got well into its stride. It has thus a poor standard period for E.P.T. British Nylon Spinners, Ltd., has just started production, and while there is much interest in the product and its future possibilities are great, there is little likelihood of much of it being available for some time to come. We presume that nylon is now in production in this country by I.C.I., Ltd.

## New Plant

### Preheating Oven

Laminated sheet, to be successfully punched or formed, should be preheated to 100-120 degrees F., depending on the grade of material, before it is worked, otherwise the material, which is brittle when cold, may chip or break. To keep such press operators constantly supplied with properly warmed resin strips, a 6-kw. convection oven has been built.

Fundamentally, the oven is a sheet-iron box feeding at the two ends and insulated on the four remaining sides with ½-in. asbestos. Eight strip heaters, four 500-watt and four 1,000-watt, are arranged under a sheet-iron plate that forms the "floor" of the heating chamber, and upon which the stacks of strips rest.

The heating chamber is 15 ins. wide, 45 ins. long and 4½ ins. high, measured from the "floor plate" to the ceiling; however, the overall inside height of the oven, including the space for the heating elements, is 10 ins.

The eight heating elements are connected in parallel across 220 volts and are controlled by a three-heat switch. "High" provides the total 6,000 watts, "medium" 3,000 watts and "low" 1,500 watts. Except when heating up, the oven is kept on "low" practically all the time. However, temperatures as high as 360 degrees F. can be obtained if desired. No thermostat is used. It is estimated that the ovens consume from 12 kw.-hr. to 20 kw.-hr. per eight-hour day when in constant operation.—E. Sandstrom, *Electrical World*.

## PERSONAL NOTES

The passing of **William Grantley Hyde,** of May and Baker, Ltd., on February 26, has deprived the Fine Chemical Industry in this country of one of its oldest and most outstanding personalities at a time when the loss of a man of his sage judgment and knowledge of the industry could be ill afforded. In 1895 Mr. Hyde joined

May and Baker, Ltd., and became secretary of the company, of which he became a director and finally chairman of the Board.

On many aspects of the trade he was an authority—and a veritable mine of information; in particular for his knowledge on bismuth, Iodides and bromides questions, he was internationally renowned. To all deliberations he brought a wise understanding of the outstanding problems and a sincere desire to achieve the greatest good for the trade as a whole. His aim for the industry was co-operation, and no negotiations were too long or too difficult for him to conduct, if the interests of the industry might be advanced thereby. When May and Baker, Ltd., entered the plastic field, especially with the introduction of cellulose acetate, he foresaw its great future and entered into this new branch with great enthusiasm.

Many readers of this journal will learn with great regret of the death of **Mr. Carleton Ellis,** the famous American plastic technologist. His knowledge of the chemistry of the subject and, indeed, of the industry in general has been said to be wider than that of any other individual. Certainly, his remarkable book on synthetic resins portrayed the width of his experience, and the amazing energy he must have spent in the collection of the information given therein. It has been estimated that the number of his patents on the production and manufacture of plastics ran into thousands. Incidentally, he was the author, too, of one of the finest and most complete books dealing with the chemistry of petroleum products.

## NEW COMPANIES

**Cables and Plastics, Ltd.**—Private company. Registered February 15. Capital, £2,000. Objects: To acquire the business of scientific instrument makers and makers of electric cables and plastic materials formerly carried on by W. Bowen as the "Cables and Plastics Co.," at 9, Newton Road, Leeds. The directors are: W. Bowen, governing director, and Sheila G. Bowen, both of 456, Harrogate Road, Leeds, 7, and R. B. Holt, 135, Alwoodley Lane, Leeds (all directors of Bowen Instrument Co., Ltd.). Registered office: 9, Newton Road, Leeds, 7.

**International Plastics, Ltd.**—Registered January 31, 1941. To execute an agreement with W. Fischbein for the purchase of certain interests in Runcolite, Ltd., British Artificial Resin, Ltd., Plastic Spray, Ltd., and International Casein, Ltd. Nominal capital, £1,000 in £1 shares. Directors: R. A. Holden, Major K. Trevor, M.C. (chairman), W. Fischbein and F. A. S. Gwatkin.

**Woodrinoid Products, Ltd.**—Registered January 29, 1941. To carry on the business of manufacturers of and dealers in buttons, buckles, ornaments. Nominal capital, £300 in £1 shares.

# RESEARCH IN THE INDUSTRY

## *The Physical Structure of Synthetic Resins*

IN recent years, intensive research on condensation and polymerization reactions has done a very great deal towards elucidating the mechanism of the formation of resinous materials. It has drawn for us a very vivid picture of comparatively simple substances, such as phenol and formaldehyde, linking together by the simple elimination of some substance, generally water, and the mutual satisfying of the bonds of intra-atomic attraction thus laid bare and of the further linking of these primary micelles to form macro-molecules of immense size with colloidal properties. It has shown us how this linking together or chemical fusion of molecules, or parts of molecules, can take place in various ways, sometimes forming long straight chains, with or without branches, and sometimes giving rise to cross-linked polymers when this process of condensation and polymerization takes place in three planes at once.

### Structure, Rigidity and Flexibility

The picture has been further extended to indicate the influence of such macro-molecular shapes on the properties of the final product. Thus, the cross-linked polymer, being bound in all directions, might be expected to possess great rigidity, and this is confirmed by experimental evidence. The long, straight chain, on the other hand, is characterized by flexibility and a low viscosity which is increased by the presence of branched chains which one can imagine as tending to interlock and so hinder free movement of the molecules. It might be anticipated, too, that the individual molecules in a long chain would be more open to attack than those sheltered inside the cross-linked polymer and, in particular, that the groups at the ends of the straight chains and their branches would have a decisive influence on the behaviour of the products towards external influences.

The picture of a resin as consisting of a mass of macro-molecules held together by intra-atomic forces has, in fact, been so successful as a basis for both qualitative and quantitative deductions that, until recently, it has remained practically unchallenged as the accepted theory by which much experimental evidence may be understood. Apart from what has already been said, it explains why it is necessary that both the primary constituents of a macro-molecular substance must be polyreactive.

It is not sufficient for only one of them to be polyreactive, and the greater the number of reactive groupings, the bigger the chance for the formation of a cross-linked structure. Again, if the distance between the reactive groups is great, with many saturated points between them, the cross-linkings will be spaced widely apart and the plastic will be soft and with a low melting point.

Conversely, reactive groupings spaced closely together tend to produce a closely knit, hard and rather inflexible product. Similarly, by examining the types of macro-molecules found in different highly polymerized materials, it is possible to predict the extent to which these different materials will be mutually soluble. This idea has been used with great success in the paint and varnish industry for the development of oil-soluble synthetic resins. Polymerized oils, which form the basis of many synthetic resin finishes, consist almost entirely of long chains, as one would infer from their mobility, and many types of resins, otherwise insoluble in the oils, have been solubilized by the introduction of long chains, free from cross linkings, into the molecule.

It also explains the complexity and non-homogeneity of resinous bodies and the presence in them of unreacted constituents. If we imagine reaction as depending on the chance contact of molecules, it will be seen that, in dealing with large molecules with comparatively small reactive areas or in which the exercise of the primary valencies is inhibited or protected by the shape and position of the substituent groups, the frequency of chance contact between the unit molecules is reduced but, at the same time, becomes of increased importance. As the progress of polymerization continues, the frequency of chance contacts must necessarily diminish and will cease, for all practical purposes, long before the theoretical limit has been reached, that is to say, before all the reactive material has been used up.

However, this theory does not tell the whole story and one of the most glaring instances is the failure to apply it accurately to the phenolic resins. The fundamental ideas seem to hold true, but the whole plan is upset by the difficulty of producing long chains in phenolic plastics. Moreover, in a recent investigation,[1] Kozlov has shown that the reduction in the strength on rise in temperature of fully hardened textolite after heating for 12 hours at 150 degrees C. renders doubtful the validity of the supposition that the mechanical properties of resins—at least, phenol resins—is directly dependent on the intra-molecular forces of macro-molecules.

In its place, he advances a most interesting theory of the physical structure of phenol - formaldehyde resins which is particularly striking in its resemblance to the accepted theory of the structure of metals and alloys. He suggests that resols consist of two phases differing in physical and chemical properties, namely, a solid and a plastic phase. The solid phase consists of a high molecular weight polymer and the plastic phase of a mutually soluble mixture of phenol-alcohols, derivatives of dioxydiphenylmethane and water. The solid phase is the disperse phase. The plastic phase acts as the dispersion medium and the catalyst functions as stabilizer.

In the process of hardening of the resol, the particles of the disperse phase desolvate and join together by the forces of cohesion into aggregates. In the resite, as distinct from the resol, the solid phase consists of short, branched aggregates of the disperse phase which are cemented together along their boundaries by the plastic dispersion medium. At the same time, the plastic phase is rendered more dense as it loses about 14 per cent. of its volatile constituents.

The drop in mechanical strength with rise in temperature of resins consisting of such a binary system is to be explained by the decrease in viscosity of the plastic phase. Confirmation for this theory of the physical structure of phenol - formaldehyde resins was obtained by an investigation of the elastic hysteresis and of the elastic after-effect of ordinary textolites and of textolites heated for 12 hours at 150 degrees C.

### Influence of Manufacturing Conditions

Textolites prepared from resols obtained using different catalysts (ammonia, sodium carbonate and barium hydroxide) differ in their mechanical properties, from which it is deduced that the catalyst must influence either the relative proportions of solid to plastic phase in the resol and resite or the properties of, at least, the plastic phase. It would be the plastic phase which would exert the decisive influence on the mechanical properties of the material and hence no assumption can be made regarding the effect of catalyst on solid phase alone.

The presence of these two phases in resites accounts for their destruction under the action of phenol and explains the nature of the decomposition products obtained. By the action of a 20-fold amount of phenol at 175 degrees C. on a powdered resite, a product was obtained which was subsequently separated by dialysis through a collodion membrane into two substances:—A powder or flakes which

were retained by the membrane and a substance soluble in alcohol which passed through the membrane.

On dialysing a solution of a resol in alcohol through parchment, two products were again obtained:—An infusible alcohol-soluble powder which was left on the dialyser and a substance which passed through the parchment and which was obtained by evaporation of the solvent in the form of a viscous mass which did not become infusible on heating. Similarly, a urea resin was separated into two substances differing in physical properties and nitrogen content.

### Group Divisions of Synthetic Resins

In general, the author divides all high molecular weight substances into three groups:—1, Products consisting of a solid solution of mutally soluble substances, such as novolacs; 2, substances consisting of two-phase systems, and 3, substances consisting of more than two phases. The last two groups can be further subdivided into (a) sphero-colloids, such as resols, resites, some pitches and asphalts, and (b) linear colloids, such as rubber, polystyrols and cellulose esters.

No doubt, all resin chemists will be fascinated by this brilliant new theory which appears to possess some degree of probability and, to say the least of it, to be backed by some experimental evidence. But to those who have also a knowledge of the structure of metals and alloys, and of the great commercial use which is made of processes which owe their inception to deductions from this theory, certain fundamental points of similarity will become immediately obvious and a conception of adapting the processes and ideas at present used in metallurgical operations to the science of plastics will open up vast new prospects for improvements.

The conception of a solid disperse phase cemented together by a plastic phase is the one adopted to explain the structure of metal alloys. There are, however, some points of fundamental difference. In metals, both phases are either elements or simple inorganic compounds and are always fusible, whereas the phases in plastics are almost certainly highly complex organic materials which, more often than not, char and decompose without fusion. The fact that the disperse phase in plastics must be amorphous should not be of great import since, although metals are usually crystalline, the disperse phase is not always so.

Moreover, there is a school of thought which seeks to draw no dividing line between crystalline and amorphous bodies.

The kind of manipulatory operations which can be envisaged through this new conception of plastic structure are concerned mainly with the relative amounts of plastic and solid phases, their constitution and also dispersion.

Presumably, strength is dependent on both these phases and, for optimum tensile strength in a particular type of resin, the latter should be formulated and treated to produce plastic and solid phases of the same strength. If the plastic phase is the stronger, the resin will fracture across the grains of solid phase, whereas, if the latter are the stronger, it will fail by fracture between the grains.

Hardness will be dependent on both phases, but ductility will not be influenced by the mechanical properties of the solid phase. A very brittle resin has a brittle plastic phase or else the bond between the phases is weak. The same probably applies to water absorption and attack by chemical reagents. It is most likely that water is absorbed into a resin by travelling along the inter-granular boundaries of plastic phase and that the softer plastic phase is more readily destroyed by chemicals than the harder solid phase. Materials of improved resistance to water and chemicals might conceivably be produced by reducing, in some way or other, the relative amount of plastic phase. Interesting results might also accrue by causing some diffusion to occur between the two phases, as is frequently done with metal alloys.

### Possibility of Applying Metal Technique to Plastics

Likewise by analogy with metal alloys, it is to be expected that improved mechanical properties could be obtained by reducing the grain size of the solid phase. The beneficial effects of grain refinement which are obtained in castings by more rapid cooling in the chill, as compared with the sand-casting process, are well known. The application to plastics of two methods of grain refinement used in metallurgical practice, namely, inoculation with crystallization nuclei, and modification by the addition of a grain-growth-inhibiting substance can be most readily envisaged.

Whether such operations will ever be carried out industrially or even whether they are feasible at all remains yet to be seen.

Another way in which plastics show some resemblance to metals and alloys is in their behaviour on moulding and, in particular, on the dependence of the electrical, physical and mechanical properties of any particular layer of the moulded product on the distance of that layer from the surface. So far as metals are concerned, this phenomenon is well known. We are all aware, for example, of the very hard surface of cast iron. Once this has been cut through, as in machining operations, the underneath metal is found to be very much softer and more easily cut and machined.

In a recent investigation of the anisotropy of cast transparent resites, Magel'dinov[2] has shown that the same effect exists in resins. For the purposes of this investigation, a phenol-formaldehyde resin plasticized with 8 per cent. triacetin was chosen.

### Structure of Cast Resins

It was cast between two parallel glass plates and, after solidification, was cut into slabs 100 mm. square which served as test-pieces. Measurements of the specific volumetric resistance, the tangent of the angle of dielectric loss at 50 Hz. and of the dielectric permeability were made on these slabs and were repeated after certain thicknesses of material had been removed from the test pieces by means of emery paper. As far as possible, the thickness of material removed from each side was kept constant.

This investigation showed beyond doubt that the specimen was not uniform in its electrical properties throughout its thickness. Electrical properties were at a minimum at the surface layer and improved steadily as the outer layers were removed.

The reverse was found to hold true for the physical and mechanical properties. These, too, are dependent on the distance of the layer, from which they are measured, from the surface of the specimen, but they are at their maximum at the surface and decrease as the layer approaches the centre.

This phenomenon of the anisotropy of cast resins can easily be explained by the theory which is accepted as underlying the related effect observed in metals. According to this, it is the outer layer of the specimen which first takes shape and solidifies, since it is in direct contact with the cool walls of the mould, followed by a progressive solidification towards the centre of the casting. This is naturally accompanied by a certain amount of shrinkage as the metal or plastic solidifies and, since the boundaries are already fixed, the inside of the product tends to be porous—to develop a honeycomb structure in which the honeycomb is of metal or plastic and the interstices constitute a partial vacuum.

Naturally, the physical and mechanical properties of such a honeycomb are lower than those of the sound material, as it exists at the surface, whereas the electrical resistance will be higher than that of the sound material.

Actually, in this investigation, attention was concentrated on the nature of the low-frequency dielectric losses in these resins, and the author has developed an interesting scheme for the measurement of low-frequency dielectric loss based on the results of a comparison of the losses with d.c. and a.c. and with different thicknesses of removed layer.

(1) P. M. Kozlov. Transactions of the Symposium of the Academy of Sciences of the U.S.S.R. on Organic Chemistry, 1939, p. 91 (in Russian).

(2) I. A. Magel'dinov. Ibid., p 141.